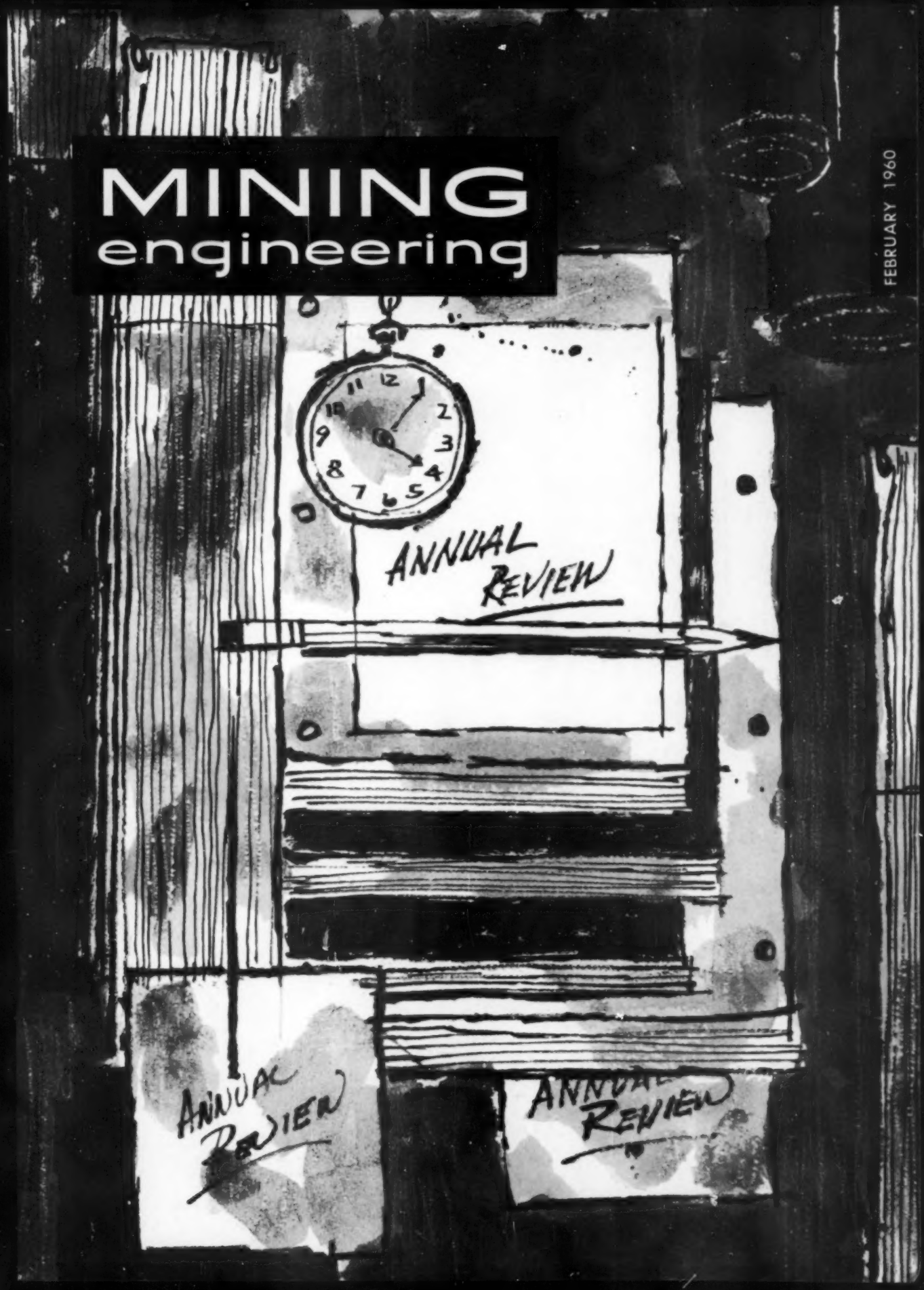
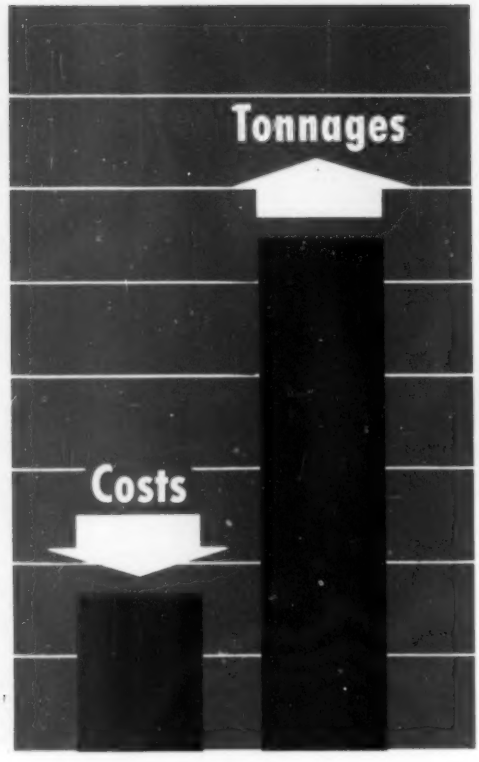
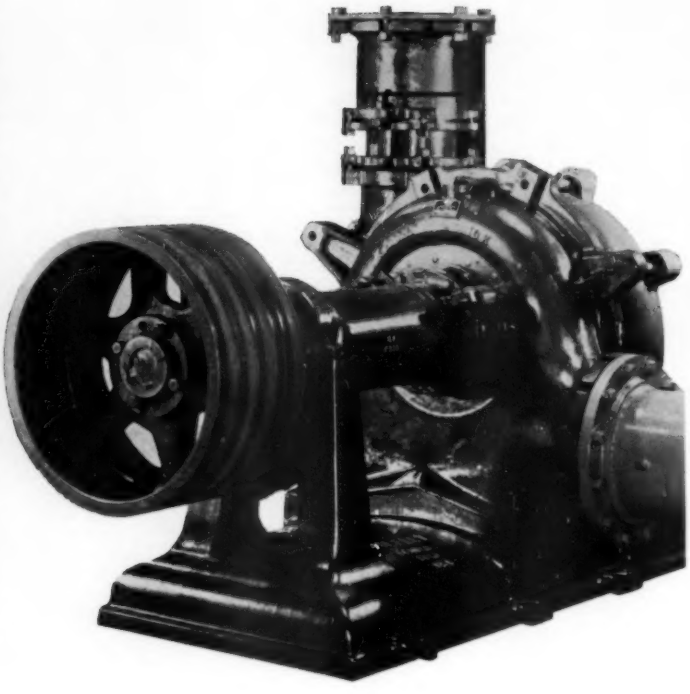
MINING engineering

FEBRUARY 1960







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COMING EVENTS

Feb. 16-17, 10th annual California Statewide meeting, Governor's Industrial Safety Conference, Fairmont Hotel, San Francisco.

Feb. 16-19, Australasian Inst. of Mining and Metallurgy, Symposium on Hydrometallurgy, "Wet Processing of Minerals and Industrial Products," Adelaide, Australia.

Mar. 2, AIME Chicago Section, "New Progress in Conventional Metal Forming Technologies" by N. H. Polakowski, Chicago.

Mar. 17-19, National Western Mining Conference, Denver Hilton Hotel, Denver.

Apr. 3-8, 1960 Nuclear Congress, sponsored by EJC, New York Coliseum, New York.

Apr. 4-6, AIME Blast Furnace, Coke Oven, and Raw Materials and National Open Hearth Steel Conferences, Palmer House, Chicago.

Apr. 6-9, International Mineral Processing Congress, sponsored by The Institution of Mining and Metallurgy, Church House, Westminster, London, England.

Apr. 11-13, 5th Alaskan Mining, Minerals & Petroleum Conference, sponsored by the AIME Alaska Section and AIME Southwest Alaska Section, CIM Yukon Section, and the University of Alaska, principal speakers: James Boyd, J. L. Gillson; campus, University of Alaska, College, Alaska.

Apr. 21-22, AIME Pacific Southwest Regional Metals and Minerals Conference, Ambassador Hotel, Los Angeles.

Apr. 25-27, CIM Annual Meeting, Royal York Hotel, Toronto.

Apr. 28-30, AIME Pacific Northwest Regional Conference, Sheraton Hotel, Portland, Ore.

May 6-8, AIME Uranium Section, annual symposium, Moab, Utah.

May 9-11, American Mining Congress, Coal Convention, Pittsburgh.

May 9-13, 2nd Southwestern Metal Exposition and Congress, ASM, State Fair Park, Dallas.

May 16-20, International Conference on Strata Control, sponsored by Charbonnages de France, Paris, France

June 5-10, ASME semi-annual meeting, Statler Hilton Hotel, Dallas.

June 10-11, Wyoming Mining Assn., Jackson Lake Lodge, Wyo.

July 11-18, 2nd World Conference on Earthquake Engineering, organized by Science Council of Japan in cooperation with Japan Soc. of Civil Engineers, Architectural Inst. of Japan, Seismological Soc. of Japan; Tokyo and Kyoto, Japan.

Aug. 15-25, International Geological Congress, Copenhagen, Denmark; for information, write Mineralogical-Geological Museum, University of Copenhagen, Oster Voldgade 7, Copenhagen K, Denmark.

Sept. 8-9, SME Coal Div. and AIME St. Louis Section, joint meeting, Chase-Park Plaza Hotels, St. Louis.

Oct. 5-7, AIME Rocky Mountain Minerals Conference, Utah Section host, Newhouse Hotel, Salt Lake City.

Oct. 6-8, 9th National Clay Conference, Purdue University, Lafayette, Ind.

Oct. 10-13, American Mining Congress, Mining Show (metal mining-industrial minerals convention, exposition), Convention Center, Las Vegas, Nev.

Nov. 4, AIME Pittsburgh Section, Off-the-Record meeting, Penn-Sheraton Hotel, Pittsburgh.

Nov. 7, AIME Pittsburgh Section, Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Nov. 7-10, Soc. of Exploration Geophysicists, annual international meeting, Galveston, Texas.

Nov. 18, American Mining Congress, coal division conference, Penn-Sheraton Hotel, Pittsburgh.

Feb. 26-Mar. 2, 1961, AIME Annual Meeting, Chase and Park-Plaza Hotels, St. Louis.

Apr. 12-14, International Symposium on Agglomeration, sponsored by SME, SPE, and TMS of AIME, Hotel Sheraton, Philadelphia.

Sept. 17-20, Commemoration of the 50th Anniversary of Froth Flotation in the U.S.A., sponsored by AIME: Society of Mining Engineers' Mineral Beneficiation Division, Cosmopolitan Hotel, Denver.

MINING engineering

Vol. 12 NO. 2 **FEBRUARY 1960**

COVER *Just as the pile of manuscripts, drawings, and papers distills into the stack of SME Preprints rising from the center of the cover by artist Herb McClure, the Annual Review issue attempts to distill a cross section of progress from the myriad of developments and activities of each year.*

ANNUAL REVIEW

121 Minerals Beneficiation

137 Mining and Exploration

- **137** USBM Progress
- **138** USGS Progress
- **139** U. S. Mineral Production

FEATURE ARTICLES

153 Water Laws Related to Mining
• *by Wells A. Hutchins*

158 Cyanide Leaching to Extract Copper from Zinc Concentrate
• *by Norman Hedley and Howard Tabachnick*

161 Energy Input and Size Distribution in Comminution
• *R. Schuhmann, Jr.*

164 Measurement of Cement Kiln Shell Temperatures
• *R. E. Boehler and N. C. Ludwig*

DEPARTMENTS

76 Personnel Service
78 Mineral Information Section
87 Manufacturers News
89 Free Literature
93 Reporter
169 SME Bulletin Board
177 Personals
184 Obituaries
188 Professional Services
192 Advertisers Index

115 Drift: Meetings for SME'ers in 1960 • *Rixford A. Beals*

FEATURED ITEMS

78 Mineral Information Section:
Books, Abstracts, Manufacturers News, Free Literature

116 Joseph L. Gillson, 1960 AIME President

169 SME Bulletin Board—Guide to Last Minute Annual Meeting Data

178 SME Available Preprint List

Index to material published in MINING ENGINEERING during 1959 will be bound into the March 1960 issue.

MINING ENGINEERING staff, Society of Mining Engineers, and AIME Officers are listed on the Drift page.

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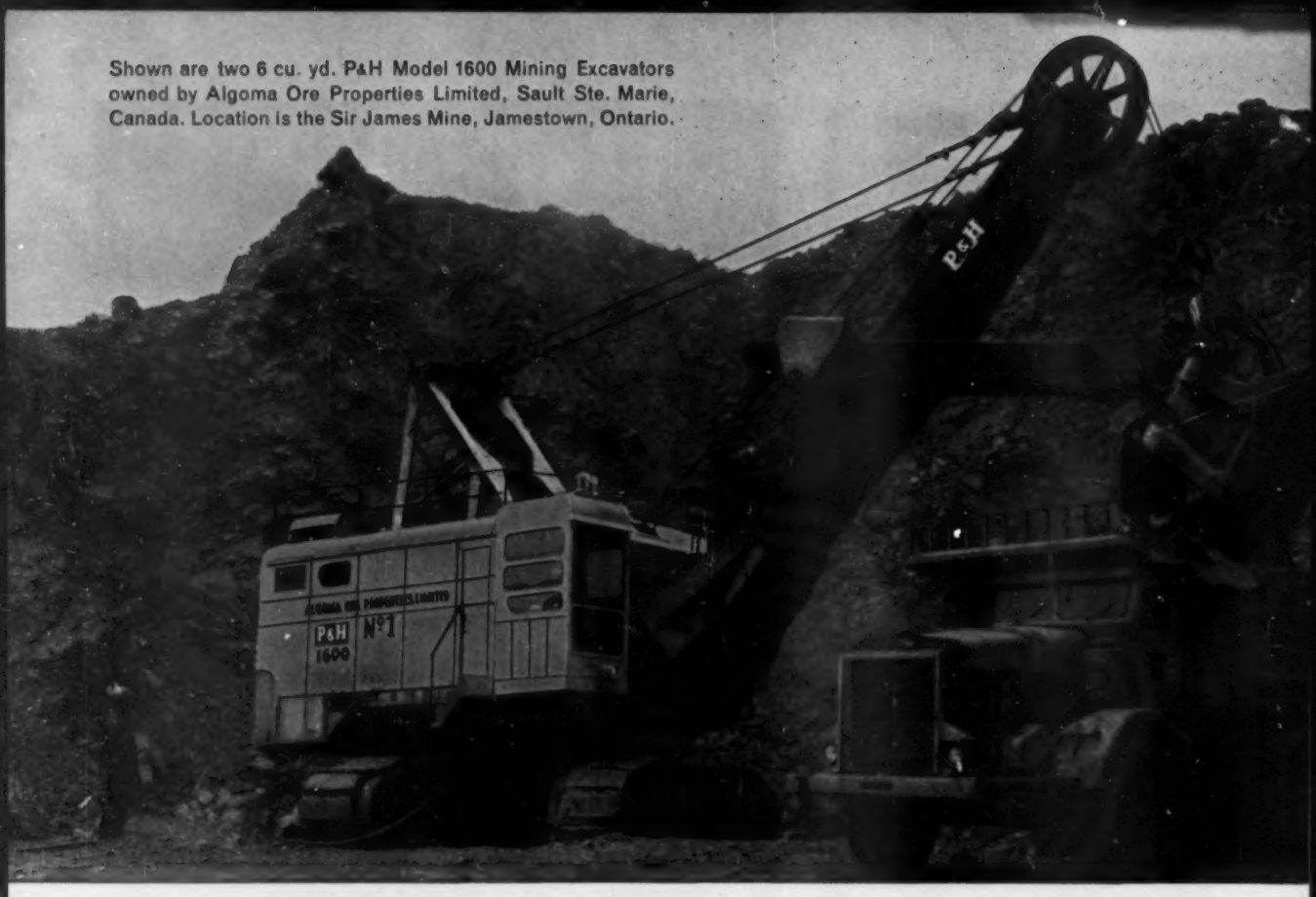

Shown are two 6 cu. yd. P&H Model 1600 Mining Excavators owned by Algoma Ore Properties Limited, Sault Ste. Marie, Canada. Location is the Sir James Mine, Jamestown, Ontario.

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In addition to the listings below, ESPS maintains a more complete file of general engineering positions and men available. Contract nearest ESPS office, listed above.

MEN AVAILABLE

Engineering Geologist, A.B., with 20 years experience in exploration geology, mineral engineering, primarily in oil and gas; also ground water, soils, sedimentation, hydrodynamics, mining and mineral deposit evaluation. Heavy experience in report writing. Consultant. Available immediately. Prefer Western U.S. or foreign. M-516.

Geologist-Petrographer, M.S. from an eastern university. Two years petrographic experience plus additional experience in geology. Desires employment in mineralogical or petrographic work. M-517.

Mining Engineer, B.S., E.M. Three years experience in exploration and development, underground and surface mapping; supervision of office, field engineering, and construction. One year teaching. Two years photomapping in the Army. Married, no children. Prefer South. M-518.

Mine Production Engineer, B.S. in mining engineering. Ten years experience in nonmetallic underground mining. Room and pillar mining including mine supervision, mine engineering, safety, ventilation control, and mine research. Also experienced in mineral exploration and cost analysis. Prefer west of Mississippi River. M-1034-Chicago.

Metallurgist, B.S. in metallurgical engineering. Thirteen years supervisory experience in most phases of ore dressing production, development, and research. Significant management and administrative experience, domestic and Latin America. Location, immaterial. M-1033-Chicago.

Manager, Superintendent, Chief Engineer, B.S. in mining engineering. Eighteen years varied mining experience, last six in top management. Energetic, good organizer in establishing new mining operations, strong in personnel, labor and community relations, financial and cost accounting. Fluent Spanish. Available immediately. Location, open. M-519.

Geologist, age 41. Five years experience in evaluation, geology, markets, ore estimates, mapping, prospecting, examination for gypsum, oil, mining properties. $8000. Prefer West. Home, Montana. Se-1761.

Geologist or Soils Engineer, M.S. in geology, age 28. Trained in soils engineering. One year as military geologist in Panama. One year research assistant in geology at a university. Three months assistant field geologist. Speak Spanish. $4800 to $6000. Any location. Home, San Francisco. Se-1714.

Superintendent, graduate mining engineer, age 53. Six years experience planning mining development and new methods of mining, design product plants, buy equipment, supervise construction and maintenance, in charge of safety and fire protection on mining base metals, gilsonite, copper. $9000. Prefer West, will consider any. Home, Utah. Se-1712.

Superintendent or Foreman, graduate mining engineer, age 49. Twelve years mining experience in Latin America. Know mining methods, mine mechanization. Good record with unions. Speak Spanish and French. $6000. Prefer Africa, South America. Home, California. Se-1699.

Mine Engineer, graduate, age 42. Professional civil engineer and mining engineer license in Washington, and mine engineer license in Alaska. Fourteen years experience construction and design of coal mines, sawmill, brick manufacturing, lumber, sand and gravel plants, including raw materials, feasibility studies, inspection, estimates, job progress, schedules, water system, drainage. Two years mine engineer on gold and coal. Three years construction experience for civil aeronautics. $10,800. Prefer U. S., Alaska, will consider any. Home, Washington. Se-1675.

Mine Superintendent, graduate, age 40. Professional engineer license in Minnesota. Sixteen years experience as plant and mine superintendent doing costs, safety, labor management, engineering, construction, maintenance, pilot plant on pyrrhotite concentrates; open pit mining of iron ore; underground and surface tin; underground, surface, and open pit copper. $12,000. Prefer West, Southwest, Midwest. Home, South. Se-1672.

Superintendent or Manager, graduate mining engineer, age 53. Experienced in mine operation, engineering, geology, and general consulting work. Nearly all phases of mining and exploration work. Wide experience in mineral deposits and geology. $9600 up. Prefer Western U. S. Home, New Mexico. Se-1477.

Designer, Supervisor, age 40. Nineteen years experience on plant design, negotiations of contracts, consulting, maintenance and engineering for mining and refining plants and electric manufacturer. $14,500. Any location in U. S. Home, New Mexico. Se-1614.

Mining or Plant Engineer, M.S. in mining engineering (mineral preparation), age 37. Two years application engineer, equipment selection, installation of machinery for manufacturing company. Two years mining engineer, survey, time study for soda ash mining. One year draft, design piping, structural, stress calculations for construction company. $7500. Prefer San Francisco Bay Area. Home, Wisconsin. Se-1597.

Production Engineer or Sales, graduate mining engineer, age 30. Over four years experience in engineering, production, and geology; open pit and underground mines. Latin American exploration and mining experience. Adept at report writing and directing men. Speak Spanish. $7800. Prefer U. S. or Mexico. Home, Cuba. Se-1590.

Supervisor, graduate mining, metallurgy, age 55. Thirty years experience in examination, exploration, development, operation, nonferrous metal mines, mills and allied fields. Licensed professional engineer. $7800. Prefer West. Home, Utah. Se-1580.

Geologist, graduate, age 41. Ten years experience as mining geologist and chief geologist and engineer at operating mines in western U. S. Single and in good health. Prefer Western U. S. or Foreign. Home, California. Se-1464.

General or Project Manager, graduate mining, metallurgy, age 47. Twenty-five years experience in mining, milling and project engineering in U. S., South America, Europe, and Australia. Thorough knowledge of management problems. Have operated own company. $12,000. Any location. Home, San Francisco Bay Area. Se-1866.

Mining Geophysicist, Geophysical Engineer, age 30. Eight years experience in mining geophysics. Two years as party chief on U. S. and foreign projects. Solid background in interpretations, geological correlation and instrumentation. $7200. Prefer Western States. Home, Arizona. Se-1365.

Director of Mineral Exploration, general engineering, age 51. Twenty-five years experience in mineral exploration and open pit mining. Desire foreign work. $18,000. Prefer Caribbean Area. Home, Oregon. Se-1332.

URANIUM-VANADIUM MILLING POSITIONS

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Grand Junction, Colorado

POSITIONS OPEN

Mining Engineer, nonmetallics, E.M., experienced in open pit operation; some underground mining helpful; experience with gravity and flotation mills, job training for supervisory level. Salary, $6000 to $6600 year. Location, Midwest. W8385.

Mining or Metallurgical Engineer, graduate preferred, with minimum of one year's experience for 500-tpd nonmetallic open pit operation. Involves project engineering in flotation and gravity, construction. Must have ore dressing background. Salary, $6000 to $6500 a year. Company will pay placement fee. Location, Northeast. W8290.

General Superintendent, mining graduate, with at least five years in major supervision open pit mining operation; thorough knowledge of drilling and blasting techniques, power shovel and truck operations, mine railroad systems and mine planning. Must speak and read Spanish. Latin American experience desired. Must be U. S. citizen. Salary, around $18,000 a year. Location, South America. F8222.

Plant Engineer with mechanical, civil, or mining engineering training and at least three years equipment operation, maintenance, and installation experience at mining or quarry property. Salary, open. Must be willing to relocate where assigned. Location, South. W8072.

Recent Graduate Engineers, either mining or civil, with courses in geology, for prospecting and exploration relating to industrial minerals. Substantial portion of time to be spent in the field. Location, South. W8037.

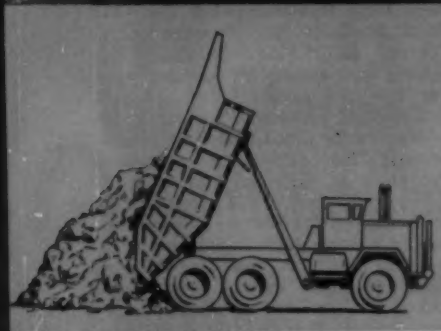
Assistant Mine Superintendent, with underground hard rock experience, to assist in supervision of all underground operations under direction of mine superintendent. Permanent. Salary, about $7000 a year to start. Location, South. W7868.

Process and Sales, understudy for plant or management in nonmetallic minerals company, mining or buying nonmetals for processing and selling in central California; start in mining, training to do labor jobs, advance to production and finally into commercial aspects. Might be a permit man in mine or mill union. Prefer to fill the need with professionally trained men. Salary, about $5400 to start. San Francisco. Sj-4904-R.

Surveying Manager, graduate civil engineering or geology, any age. Top experience in directing surveys for topographic and hydrographic large area mapping relating to development of land, beach, and waterfront properties for residential and commercial usage in an undeveloped area. Must be qualified to build up his own survey, drafting, and mapping staff and exercise general superintendency over the activities. Single status to start, home later. For a land development enterprise. Salary, $9600 to $12,000. Mexico. Sj-4854.

Assistant Mine Superintendent, graduate mining engineer, with substantial experience in underground mining in South America and able to speak Spanish. Family housing, transportation for family, children to age 12. $6600 to $7200 plus 2½ months benefits per year. Three-year contract. South America. Sj-4861.

Sales Engineer, young, with experience in gravity separation and flotation equipment, capable of laying out flowsheets and plant design and familiar with testing procedure, evaluations, and initial startups. Salary, open. Location, eastern U. S. W7665.



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World Directories of Mineral Industries Educators, compiled by Howard L. Hartman under auspices of the Education Committee of the Society of Mining Engineers of AIME. Copies are available to interested AIME members at 25¢ per copy. Write to: *Dr. John J. Schanz, Jr., Secretary-Treasurer, Council of Education of AIME, 206 Mineral Sciences Building, The Pennsylvania State University, University Park, Pa.* The Directories contains names and addresses of universities and faculty members associated with mineral industries engineering and technology on an international level. In addition metallurgical and petroleum educators are listed for the United States. The latter two lists were provided by the Education Committees of the AIME Society of Petroleum Engineers and The Metallurgical Society.

Gmelins Handbuch, eighth edition, *Verlag Chemie,* Weinheim, Germany, **Fluor, System No. 5,** Ergänzungsband, 258 pp., $36, 1959; **Silicium, System No. 15,** Teil C., 501 pp., $67.44, 1958; **Eisen, System No. 59,** Ergänzungsband, 580 pp., $77.04—Three new volumes have been added to this extensive reference work. The volume on flourine covers literature from 1926 to 1949. The addition to the silicon volumes deals specifically with the preparation, constitution, properties, and applications of the organosilicon compounds. Essentially a supplement to the previous volumes on iron, an extensive treatment of magnetic materials covers their constitution and properties. • • •

Chemische Reaktionen in Stosswellen, by E. F. Greene and J. P. Toennies, *Dr. Dietrich Steinkopff Verlag,* Darmstadt, Germany, 202 pp., approx. $5.95 (25 DM), 1959—This is a German translation of an English language manuscript dealing with chemical reactions in shock waves. Engineers interested in the investigation of fast gas reactions will find this work useful. • • •

Geology for Engineers, by Joseph M. Trefethen, second edition, *D. Van Nostrand Co. Inc.,* 120 Alexander St., Princeton, N. J., 632 pp., $8.50, 1959—After a discussion of the most important minerals, this text deals with igneous activity and products of weathering, derives the sediments, and follows the deformation and metamorphism of the rocks. • • •

The Physical Chemistry of Copper Smelting, by R. W. Ruddle, *The Institution of Mining and Metallurgy,* 44 Portland Place, London W.1, England, 156 pp., $2.80, 1953—This review includes chapters on smelting process, the constitution of matte and copper smelting slags, and the formation of magnetite.

Extraction and Refining of the Rarer Metals, volume of proceedings from **Symposium on Extraction Metallurgy of Some of the Less Common Metals,** London, Mar. 22 to 23, 1956, *The Institution of Mining And Metallurgy,* 44 Portland Place, London W.1, $8.50, 1957. • • •

Accounting for Oil and Gas Producers, by C. Aubrey Smith and Horace R. Brock, *Prentice-Hall Inc.,* 536 pp., $8, 1959—Description of accounting principles, policies, and procedures which takes into account the many variations in existing practice is the major portion of this work. In addition to accounting problems, many collateral subjects are covered, relating to geological and geophysical aspects. • • •

Chemical Engineering Plant Design, by Frank C. Vilbrandt and Charles E. Dryden, *McGraw-Hill Book Co. Inc.,* fourth edition, 534 pp., $12, 1959—This new edition emphasizes the logical development of a chemical process from its inception in the research laboratory to the successive stages of pilot plant development, process design, preliminary plant design, and economics. • • •

Symposium on Bulk Sampling, 1958, published as Special Technical Publication No. 242 by the *American Society for Testing Materials,* 1916 Race St., Philadelphia 3, Pa., 60 pp., $2.25, 1959—Among the topics discussed are measurement error factors in bulk sampling, the problems faced in sampling a particular class of bulk material, and the sampling of coal and similar materials. • • •

Rocks to Riches, by Charles H. Dunning with Edward H. Peplow, Jr., illustrations by Larry Toschik, *Southwest Publishing Co. Inc.,* 817 West Madison St., Phoenix, Ariz., 414 pp., $8.75, 1959.—Originally intended as a history of Arizona mining, the book plan was expanded to include the nonferrous industry in general with discussions of its economics. The author is considered the dean of Arizona mining engineers with over 50 years experience in mining in the southwest. In addition to a chronological history of Arizona mining; an analysis of complex problems facing the mining industry today; and tabulations covering production, metal prices, exports, imports, etc.; this volume contains a "Compendium of Important Arizona Mines," which presents facts about some 200 mines. Also included are summary data for over 40 indigenous minerals or metals. • • •

STATE PUBLICATIONS

Connecticut

Robert C. Sale
State Librarian
State Library
Hartford, Conn.

The Bedrock Geology of the Middletown Quadrangle, Quadrangle Report No. 8, $1, including map: map alone, 25¢, 1959.

Florida

Florida Geological Survey
P. O. Box 631
Tallahassee, Fla.

Bibliography and index of articles relating to the ground-water resources of Florida, Special Publication 4, gratis, 1959.
Some Geomorphic Features of Central Peninsular Florida, Bulletin 41, gratis, 1958.
Record of Wells in Manatee County, Florida, Information Circular 19, gratis.
Ground-Water Resources of Manatee County, Florida, Report of Investigations 18, gratis, 1958.
Thermodynamics of Fluorocarbon-Hydrocarbon Mixtures, Technical Paper No. 165, gratis, 1959.
Studies in Binary Mixtures, Technical Paper No. 166, gratis, 1959.
Turbidity Effects in Natural Waters In Relation to Organisms and the Uptake of Radioisotopes, Technical Paper No. 167, gratis, 1959.

Idaho

Idaho Bureau of Mines & Geology
Moscow, Idaho

Geology of the Uranium Deposits near Stanley, Custer County, Idaho, Pamphlet No. 117, $1, 1959.

(Continued on page 80)

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Geology and Mineral Resources of the North Fork Quadrangle, Lemhi County, Idaho, Pamphlet No. 118, $1.25, 1959.

Illinois

State Geological Survey
Natural Resources Bldg.
Urbana, Ill.

Rocks and Minerals of Illinois, Educational Series 5, 25¢, 1959.
Geology of Buda Quandrangle, Circular 275, gratis, 1959.
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ABSTRACTS

In This Issue: *The following abstracts of papers in this issue are reproduced for the convenience of members who wish to maintain a reference card file and for the use of librarians and abstracting services. At the end of each abstract is given the proper permanent reference to the paper for bibliography purposes.*

Water Laws Related to Mining by *Wells A. Hutchins* (TP 59H1)—The title connotes legal water problems currently or prospectively connected with the establishment and operation of mines and the processing of their products. Water laws that have such significance comprise not only statutes and court decision of general applicability but also some that relate specifically to mining water rights and to the handling of water in mining and related operations. They govern or affect rights to the use of water, the disposal of water after use in mining or milling operations, and the discharge of waste materials into watercourses. **Ref.: (MINING ENGINEERING, February 1960) AIME Trans., 1960, Vol. 217, p. 153.**

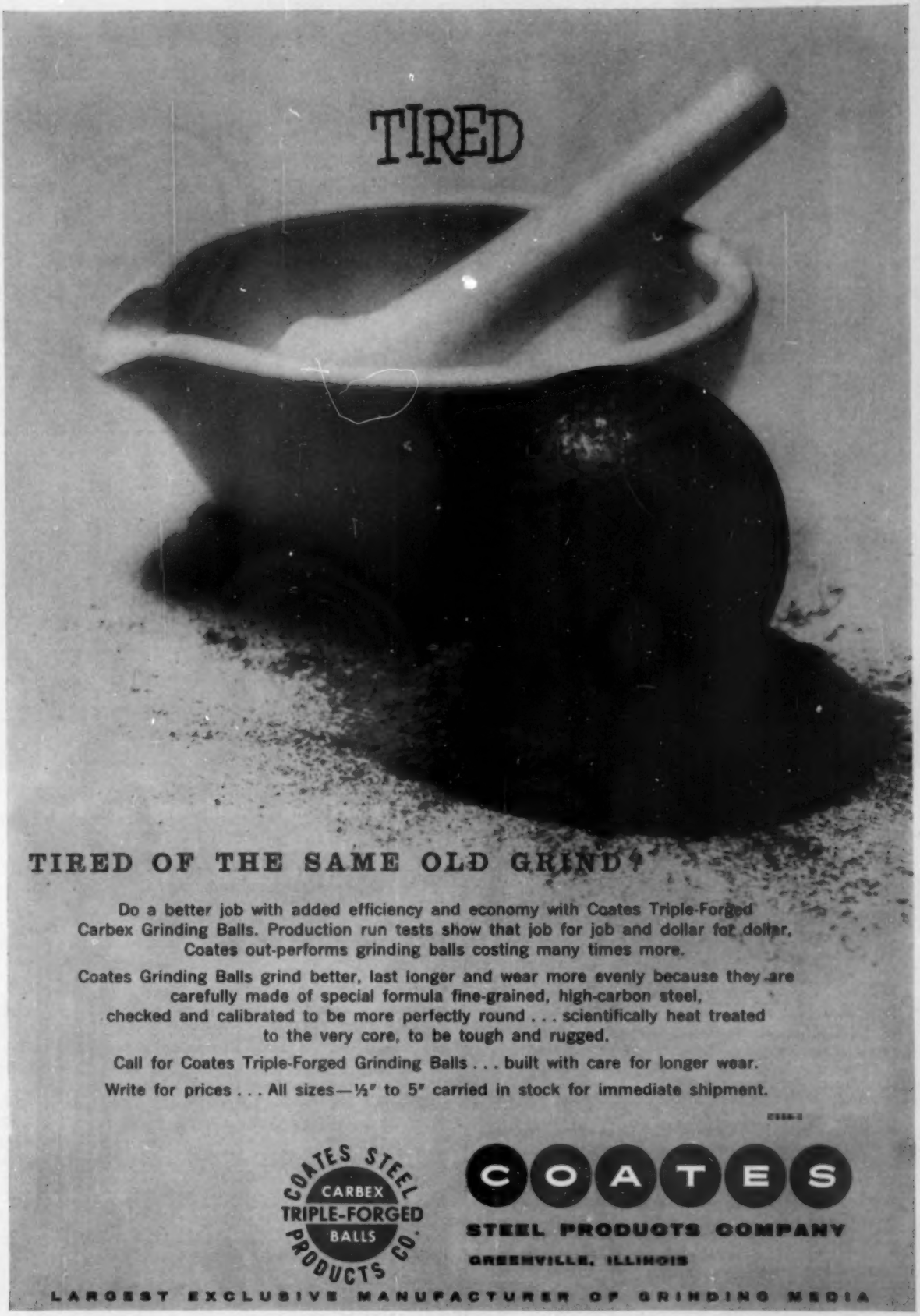
Cyanide Leaching to Extract Copper From Zinc Concentrate by *Norman Hedley and Howard Tabachnick* (TP 59B207)—Extraction of gold and silver from ores with alkaline cyanide solutions is well known. Cyanide solutions are also good solvents for many base metal minerals, particularly most of the copper ones. The authors present results of their experiments with cyanide leaching to reduce the copper content of a zinc concentrate from 0.050 pct to the desired specification of less than 0.02 pct. **Ref.: (MINING ENGINEERING, February 1960) AIME Trans., 1960, vol. 217, p. 159.**

Energy Input and Size Distribution in Comminution by *R. Schuhmann, Jr.* (TP 60B11)—When the distribution of material in the fine sizes of a comminution product can be represented by the empirical equation, $y = 100\left(\frac{x}{k}\right)^{\alpha}$, it is shown that the energy input is given by $E = Ak^{-\alpha}$ and that the same constants k and α are involved in both the size distribution energy equations. These derivations support a basic and very practical definition of grindability $\left(\frac{1}{A}\right)$ as the quantity of comminuted materials finer than unit size produced per unit of energy expended. Finally, it is pointed out that the hypotheses of Kick, Rittinger, and Bond all work equally well in calculating theoretical energy requirements from size distribution data, so that there is no point in attempting to give a special significance to any one of these hypotheses. **Ref.: (MINING ENGINEERING, February 1960) AIME Trans., 1960, vol. 217, p. 161.**

Measurement of Cement Kiln Shell Temperatures by *R. E. Boehler and N. C. Ludwig* (TP 59H56)—Experiences in measuring cement kiln shell temperatures with calibrated melting point crayons, paints with color sensitive pigments, aluminum paints, metal stem thermometers, and radiation pyrometers are described. Work with the radiation pyrometers showed that this method was greatly superior to the others, especially in determining areas of hot spot formation. The development of a traveling radiation pyrometer for either continuous or intermittent scanning is described. **Ref.: (MINING ENGINEERING, February 1960) AIME Trans., 1960, vol. 217, p. 164.**

SME Meeting Papers: *The following abstracts of papers presented at SME meetings are given for your information. Copies of these papers are available* **only if followed by a preprint order number.** *These preprints are obtained on a coupon basis. The coupon books may be purchased from SME headquarters for $5.00 a book (10 coupons) for mem-*

(Continued on page 82)



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bers of AIME or $10.00 a book for non-members. Each coupon, properly filled out, entitles the purchaser to one preprint. Mail completed coupons to Preprints, Society of Mining Engineers, 29 W. 39th St., New York 18, N. Y.

Coal Seam Degasification by Horizontal and Vertical Drilling, by *G. R. Spindler and W. N. Poundstone*—Progress is reported in experimental work sponsored by the Christopher Coal Co., Morgantown, W. Va., and the School of Mines of West Virginia University. The work is confined entirely to the Pittsburgh coal bed on properties operated by Christopher in Monongalia County, W. Va., and Greene County, Pa. The program began in 1952 with experiments with vertical drill holes from the surface and has been continued since that time with additional vertical drilling and with horizontal holes in the coal seam drilled from underground working faces. It has been demonstrated that with coal seam and methane liberation characteristics typical of the Pittsburgh coal seams in the area under study, methane can be removed in considerable quantity from the coal and/or the adjacent strata with indicated improvement of conditions related to the subsequent extraction of the coal. The work to date has been purely exploratory and it is not claimed that the methods employed represent a practicable approach to general or large-scale degasification of coal seams in advance of mining. Some interesting and useful information has been obtained and the program will be continued with the expectation that better understanding of the properties of coal seams with respect to methane liberation may lead to a solution that will facilitate the safer and more economical mining of coal. **AIME Annual Meeting, New York, February 1960.**

Characteristics of Coal Preparation Plant Slurries by *H. B. Charmbury*—Waste Solids in the slurries from eight preparation plants in Pennsylvania ranged from 56 to 725 tpd. All of the solids in some of the slurries were sufficiently low in ash and sulfur that they represented salable coal. In other slurries the solids would have to be processed to make a marketable product and in these cases the recoveries may be as low as 10 pct. However, based upon the average figure given above, and applying this figure to the 96 coal preparation plants in Pennsylvania alone, over 4 million tons of recoverable coal is being discharged from these plants. Assuming an average value of $5 per ton, this is equivalent to a $20 million loss per year. **AIME Annual Meeting, February 1960.**

Adsorption of Silicic Acid on Thoria Determined by Infrared Spectroscopy by *G. J. Spaepen, R. T. Wimber, and M. E. Wadsworth*—Adsorption isotherms were obtained for silicic acid adsorbed on thoria from aqueous solutions at 16°, 49.6°, and 71.5°C. Typical Langmuir isotherms were obtained from which the equilibrium constants could be calculated. Additional equilibrium constants were obtained by equilibrating in an autoclave from which flash samples were removed up to temperatures of 280°C. The amount of silica adsorbed was determined from infrared spectra of the adsorbate on the surface of the thoria. It was found that the silicic acid adsorbed with a positive enthalpy and entropy of adsorption. The equilibrium constants increased with temperature to a maximum and then decreased above 230°C. The abnormal, positive enthalpy and large positive entropy have been explained in terms of the adsorption of a silicic acid polymer on the surface of thoria involving the breakup of polymer chains and the splitting-out of water from the surface of thoria. At elevated temperatures the length of the polymer chain breaks down, thereby causing the equilibrium constant to go through a maximum and then diminish, thus explaining the weaker adsorption of silicic acid above 280°C. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Reflection Infrared Studies of Films Adsorbed on Metal Surfaces from Carboxylic Acid Solutions by *A. H. Ellison and S. A. Francis*—Reflection infrared spectra were obtained and interpreted for films formed on metal surfaces when such surfaces were exposed to solutions of carboxylic acids in cetane. Stearic and perfluorodecanoic acids were used to prepare films on Ag, Al, Cu, cold-rolled steel, stainless steel, Ni, Pt, and Zn mirrors. Stearate soap films were formed by reaction between the mirror surface and the dissolved acid in the cases of Al, Cu, cold-rolled steel, stainless steel, Ni and Zn but not with Ag or Pt. Perfluorodecanoate soap films were formed by reaction with the dissolved acid on all of the metals. The unexpected formation of a perfluoro soap film on Pt was found to occur only when the mirror cleaning procedure used prior to the adsorption was likely to leave an oxide film on the Pt. In many cases soap film formation did not stop when a monolayer was formed but rather continued with time. Both stearate and perfluorodecanoate soap films showed a preferred molecular orientation with the long axes of the molecules normal to the surface. This orientation was found in multilayer as well as monolayer films. It was shown that multilayer soap films could be formed on metal surfaces by a mechanism involving diffusion of one of the reactants through the initially formed layers. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Environment Effects on the Brittle Fracture of Zinc Single Crystals by *L. C. Weiner and M. Gensamer*—Liquid and gaseous environments are found to affect the cleavage strength of zinc single crystals in tension at room temperature, only when the environment reacts with the crystal to form an adherent solid surface film having a thickness above a certain small critical value. As a result, further experimentation was focused on the effects of solid surface films on the brittle fracture of these crystals. The normal fracture stress of crystals oriented $\phi = 3°$ is increased 43 pct upon applying a surface film of copper, gold, zinc oxide, tin, or zinc thicker than a few hundred Angstroms. Above this critical thickness, this increase in strength is found to be independent of film thickness and film material. Results of experiments, as well as observations on prestrain, recovery, and film removal experiments are presented in the paper. Also, the temperature dependence of flow and fracture have been explained by a dislocation model in which twins play an important role by modifying the dislocation path and acting as barriers. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

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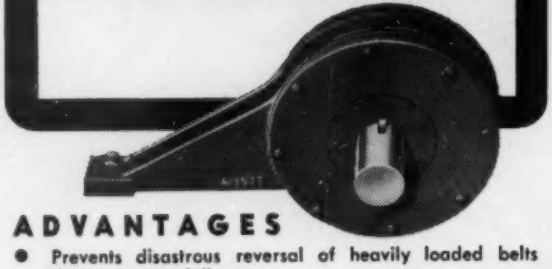

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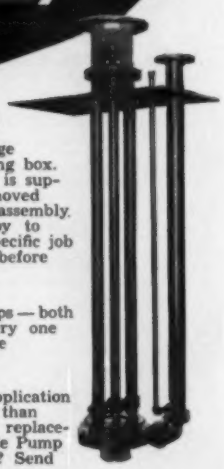

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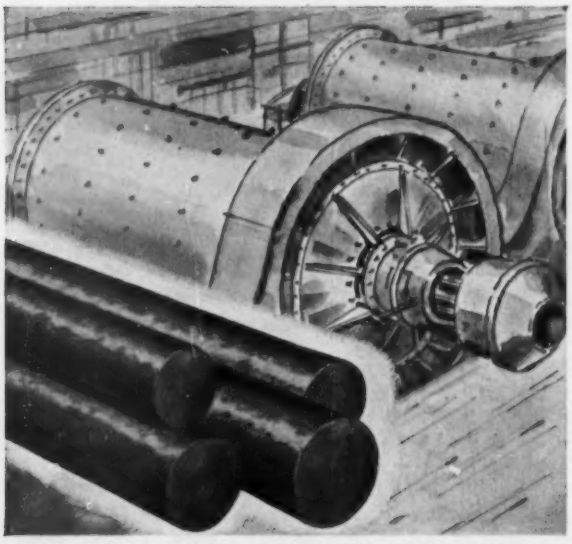

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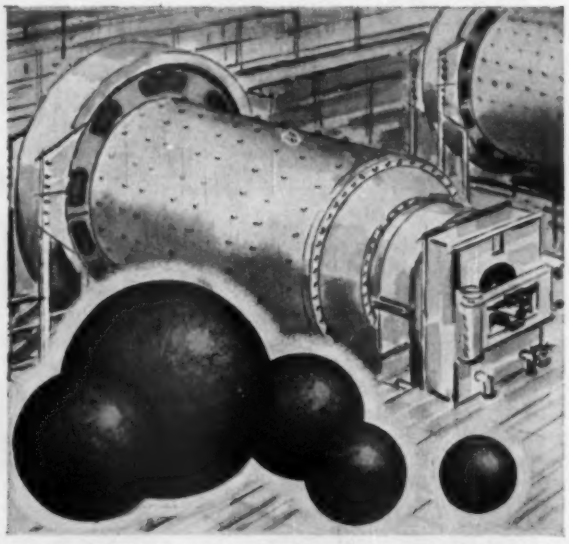

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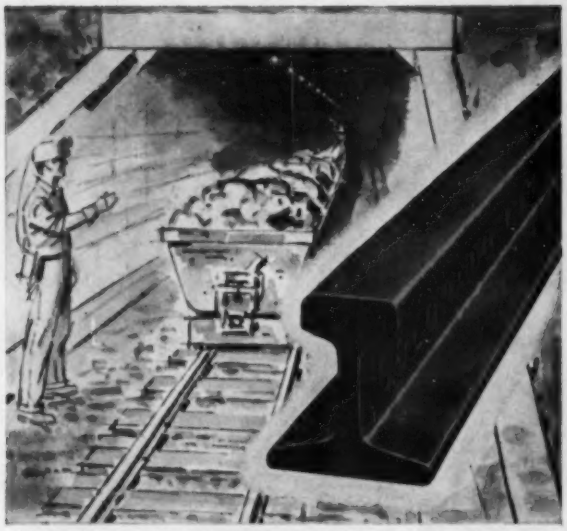

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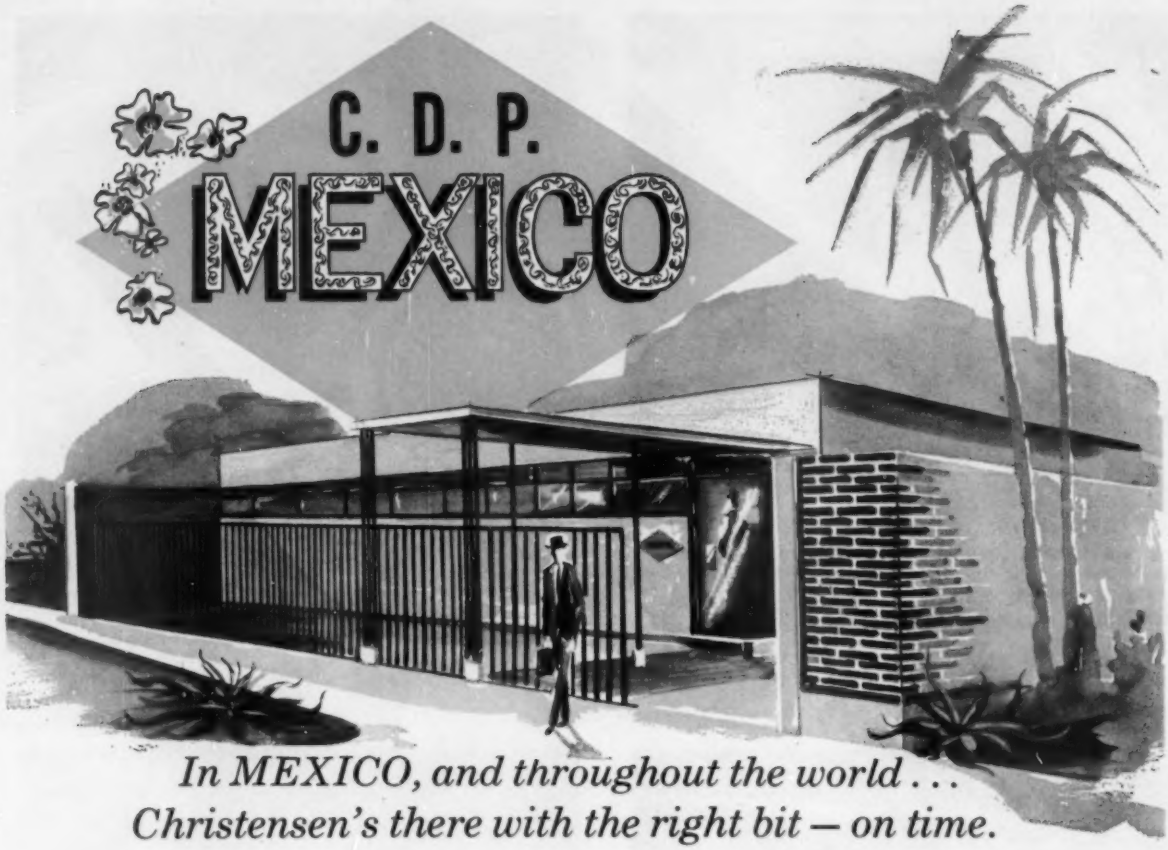

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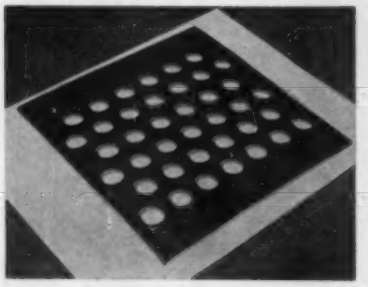

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other carriers has been announced by *Jebco Inc.* Having a 30-ft conveyor that reaches 15½ ft at the discharge end, the Jeb-Loader can cast up to 1750 yd per hr and load up to 800 yd per hr. A 32-in. diam cutting disk feeds material to a trough shaped belt traveling at 600 fpm. **Circle No. 4.**

Vibro-Energy Mill

The Vibro-Energy mill now being placed on the U.S. market by *Southwestern Engineering Co.* in association with two English firms utilizes a new process for precision fine grinding of a wide variety of materials. The mill applies high frequency vibration and circular movement to a grinding media which in turn effects particle size reduction of product to sub-micron range. **Circle No. 5.**

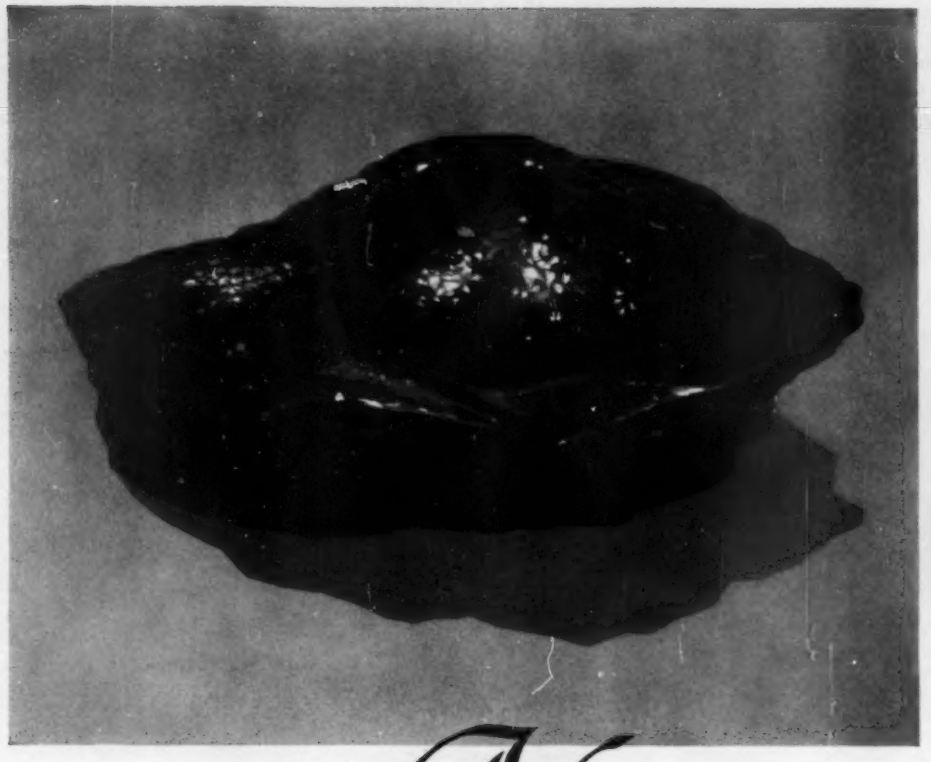
Miniature Seismograph

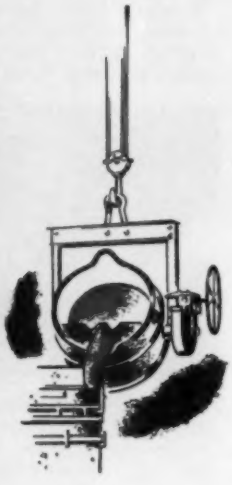
Reliable cost estimates without costly drilling can be provided mining engineers and producers of stone products through better subsurface engineering information. New miniature seismograph built by *Geophysical Specialties Co.* yields data for precise depth to bedrock determinations and accurate identification of bedrock. Operation of 16-lb unit calls for only two men. Seismic impulses are provided by sledge hammer, and measured by an electric counter. Under ordinary conditions it is estimated that two men with one instrument can complete three quarters of a mile of profiles with 200-ft stations. **Circle No. 6.**

News & Notes

Birdsboro Steel Foundry & Machine Co. of Birdsboro, Pa., which dates back before the American Revolution, has changed its name to the Birdsboro Corp. "We elected to change the corporate name because it was no longer descriptive of our product diversification," said company president Clymer . . . Determinant Tempering, a patented thermal process for improving alloy steel and other castings has been developed by *The Eimco Corp.* The process adds even greater strength to and uniform quality to the great number of alloy steel castings utilized in their crawler tractors, mining equipment, and other heavy industrial products, according to the company. . . . *Industrias Quimicas de Mexico, S. A.*, has begun construction of a plant at Morelia, Mexico, to produce xanthates. This affiliate of Staxuffer Chemical Co. will be the first plant in Mexico to produce xanthates . . . *Hardinge Mfg. Co.*, a subsidiary of Hardinge Co., will spend $300,000 to expand and modernize its foundry facilities for better service on castings and jobbing work.

The Allen-Sherman-Hoff Pump Co. has moved its headquarters from Wynnewood, Pa. to this new building in Philadelphia's suburban area near Paoli. Occupied by the sales, service, and engineering staffs. Address: P.O. Box 635, Paoli, Pa.





Hematite

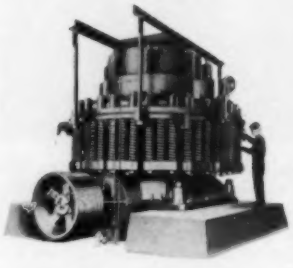
Fe_2O_3

...life blood of Industry

Derived from the Greek word meaning blood, or blood-like, Hematite was so named because of the reddish hue found in most of its varieties. This important mineral has indeed provided "life blood" for the iron and steel sinews of industry. For many decades, Hematite—the basic ingredient which feeds the blast furnaces of the world—has been one of the most important minerals of civilization.

Symons Cone Crushers, with their great capacity for finely crushed material at low cost, have been an important factor in the efficient reduction of the Hematite, as well as the Magnetite and Taconite iron ores throughout the world, and have established outstanding production records in keeping pace with industry's insatiable demands.

NORDBERG MFG. CO., Milwaukee 1, Wisconsin



SYMONS CONE CRUSHERS

. . . The machines that revolutionized crushing practice . . . **are built in a wide range of sizes, for capacities to over 900 tons per hour. Write for descriptive literature.**

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SAN FRANCISCO • TAMPA • WASHINGTON • TORONTO • VANCOUVER • JOHANNESBURG • LONDON • MEXICO, D. F.

(21) BETTER COMMUNICATIONS: Need two-way radio? More and more firms are turning to this versatile means of bettering transmission of information, speeding operations, cutting downtime. *Collins* 32RS-1 100-watt Transceiver, one of several models, may meet your needs. This compact station features simplified controls for operation by nontechnical personnel, and accessory kits available include various antennas, phone patch and wattmeter. Unit can be tied into any communications set-up including teletype, telephone, or internal phone system.

(22) MINE CAR WHEELS: A new four-page booklet tells how *Bethlehem* forged-steel mine car wheels speed haulage, increase safety, and reduce maintenance. A special forging process to give these wheels greater strength and toughness is described.

(23) DIAMOND DRILL: Bulletin 31 from *Acker Drill Co.* describes their new Presidente core drill with capacity for depths to 4500 ft. Unit is also suitable for operation as a 6-in. rotary to depths of 1500 ft. Among features described are automatic chuck, two speed ranges, and hydraulic drill head. Diesel, or gasoline drive is available, a full line of steel masts are built, and mounting may be truck or skid.

(24) VIBRATING MILLS: A new line of German-made vibrating mills, the Vibratom line, are described in a bulletin issued by the *Schutz-O'Neill Co.* The complete line includes six batch loaded models (from one pint to 55-gal size) and four continuous system models.

(25) JAW CRUSHERS: Operating advantages of the A-1 jaw crusher are outlined in bulletin 17B6369E from *Allis-Chalmers*, which also includes dimensions and capacity tables for these double toggle crushers.

(26) ROTARY COMPRESSORS: Clean styling and a flip-top housing

FREE LITERATURE

are two of the features of the *Le Roi* 75RG1 single stage rotary compressor. Gasoline powered unit is the fifth in the Le Roi line and is designed for small jobs requiring a light, mobile supply of 75 cfm.

(27) NEW MINING CHEMICALS: A book that describes the new products made available by *American Cyanamid Co.'s* mining chemicals research laboratory is now offered by the company's explosives and mining chemicals department. "New Developments in Mining Chemicals" is the title of the 12-page book which lists only those materials that have been tested in the laboratory and found to have enough promise to warrant further testing in the field.

Descriptive data and suggested uses are summarized for 13 products. Included are four nonmetallic metallic oxide promoters, three sulfide metallic-mineral promoters, an emulsifying-frothing agent, two antiprecipitants, two carbon control agents for cyanidation, and a film forming coating agent.

(28) ELECTRIC SCREENS: An illustrated 24-page catalog offered by *W. S. Tyler Co.* describes operating principles and application of Hummer electric screens. Unequalled economy is claimed for these screens when used in appropriate service. The Hum-mer design has no bearings, reducing attention needed, and have low power requirements.

(29) WEIGHING SYSTEM: Data sheet from *Webber Air-Weigh Co.* describes load-cell operated air transmitted weighing systems capable of 0 to 200,000 lb tanks, bins conveyor loads, truck tanks and the like.

(30) WELDING ELECTRODES: New products and new engineering data have been added to the most recent edition of *Air Reduction Sales Co's* "Electrode Pocket Guide." The 64-page booklet contains complete information on all types of electrodes available from Airco, together with user information for application.

(31) MOTIVE POWER BATTERIES: An illustrated 4-page bulletin by *C&D Batteries* describes how new AccuPak plates eliminate possibility of low cells and extend life of heavy duty cells for operation of mine and tunnel haulage equipment.

CONSTRUCTION EQUIPMENT New literature covering construction machinery manufactured by *Allis-Chalmers* is now available from the construction Machinery Div. (Request items by circling appropriate numbers on reader service card below, key numbers are bold face.) Form 1092 (**32**) pictorially reviews the A-C 7000 lb capacity rubber tired TL-16 Tractoloader. Another is No. 1093 (**33**) directing attention to the company's 9000 lb TL-20 Tractoloader. Another piece of literature is MS-1133 (**34**), a newly revised catalog on the A-C HD-11G tractor shovel. Illustrations are also used graphically to tell its construction features and work potentials.

The Allis-Chalmers 45 Motor Grader engineering design and construction features are described in MS-1148 (**35**). The story on the products of the recently acquired Deerfield Works is related in brochure MS-1348 (**36**) complete with photographs of the works and its line of seven Tractoloaders and attachments. Engineering developments and research are also covered. Specifications are included in most of the above booklets.

(37) FIRST AID: The M-S-A flip-top box for multiple-use first aid units is described in bulletin 0401-8 issued by *Mine Safety Appliances Co.* The illustrated release highlights construction features of the container including resistance to tearing,

mail this post card for more information

2

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after May 15, 1960

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64						

Students should write direct to manufacturer.

protection against dust, and convenience in use.

(38) BIGGER SCRAPER: The 28-yd, 360-hp model B Tournapull, largest self-propelled scraper in the *Le Tourneau-Westinghouse* equipment line, is the subject of brochure TP-433 released by the company. Speed, power, and agility of the big machine are pointed out as prime attributes of the machine in these four-color illustrated 16-page booklet. Among other features shown is that a 35-ton rear dump or 30-ton crane readily interchange behind the standard model B prime mover.

(39) CATIONIC CHEMICALS: *Armour Industrial Chemical Co.* has just published a booklet on cationic chemicals as conditioners for hygroscopic salts and fertilizers. The booklet covers nine Armour chemicals and new formulations used for conditioning fertilizers and salts and five methods of application and recommended uses. Examples of the effects of conditioners on various single minerals and fertilizer blends are shown graphically. In addition, flow diagrams depict application of reagents under pilot plant conditions. Detailed results of extensive tests and full-scale plant operations with granulated and pelletized fertilizers are included.

(40) BULK HANDLING: Case histories illustrating recent advances in the handling of bulk materials by adaptation of pneumatic equipment are the subject fact file ER-G-6 issued by the *Fuller Co.* Nineteen photographs in the 8-page technical report show a wide diversity of equipment in operation for loading, unloading, transfer and other operations between transportation units and storage points.

(41) GUAR GUM: A new edition of a 16-page booklet on Jaguar guar gum from *Stein Hall & Co.* contains additional information on physical and chemical properties of the gum gained since the first edition of the booklet was released in 1956.

(42) FILTER CLOTH: *Wheelabrator Corp.* offers a handy comparison chart as a guide to the selection of filter cloths commonly used in dust and fume collectors. Cotton, nylon, orlon, dacron, and silicone treated glasses are classified according to temperatures limits, strength, resistance to acid or alkali or abrasion, and relative cost per bag. Since each fabric possesses qualities favorable to certain of these basic conditions, selection can be readily determined on the basis of particular needs.

(43) CONTROLS: General purpose control catalog GEC-1260D is a 72-page publication containing information on the complete line of control devices manufactured by *General Electric's* control department. Horsepower selection charts are listed for motors from ¼ through 200 hp, providing quick selection of starters, heaters, and push-button stations. Pricing tables for each device are included with descriptive information.

(44) MINE DRILLS: A 12-page bulletin (KMO-633) describing the Ka-Mo line of horizontal, vertical, and angular drilling and boring equipment is available from the *Kwik-Mix Co.*, a division of Koehring Co. The bulletin discusses the wide variety of air, hydraulic electric, and gasoline powered Ka-Mo drills available, and has on-the-job photos of units working in clay, sand, gumbo, frozen ground, shale, limestone, etc. A special feature of the bulletin is a handy reference guide to the entire line, showing drill size, type of cutting head, drive size, drill weight, drill feed, drive, and model applications. Drills range in capacity from 2¼ to 36-in. diam and include a variety of specialized cutting heads, such as spiral, drum, and rock lifter types.

(45) COOLERS & DRYERS: *The Jeffrey Mfg. Co.* has just issued catalog 953, a comprehensive 32-page book covering electric and mechanical vibrating type coolers and dryers of both direct and indirect type. Included are sections on basic drying principles and the TMV variable amplitude unit. Pages are also devoted to auxiliary equipment in the vibrating line, such as feeders, conveyors, magnetic separators, packers, controls, and the Waytrol constant weight feeder. A pilot unit rental system that permits firms to simulate actual production conditions in their own plants is also outlined.

(46) EXCAVATOR JOBS: A new well-illustrated bulletin (L-1091) from *The Eimco Corp.* outlines the use of their Eimco 105 excavator on three recent major jobs in the U. S. Facts and figures are given on the Glen Canyon Dam Tunnels, the Fort Pitt Tunnels in Pittsburgh, and the Mammoth Pool Diversion Tunnel. All of these utilize the unique overhead loading action and maneuverability of the 105 excavator. Specifications of the machine are also provided.

TRANSMISSION CONTROL: A step-by-step explanation of how the new SynchroTouch transmission control operates is given in new 8-page booklets on the 345 hp *Caterpillar* DW20 and DW21 series G tractors. Schematic drawings illustrate the sequence of events involved in shifting by dialing the desired gear. Maximum rimpull of 39,565 lb for the DW20 and 49,250 lb for the DW21, both higher than on previous models, are combined with the SynchroTouch transmission control to produce increased travel speeds 10 to 20 pct greater over similar haul road conditions. Circle **(47)** for data on the DW20, and circle **(48)** for data on the larger DW21.

(49) IMPACT BREAKERS: The full story on Cedarapids double impeller impact breakers, built by *Iowa Mfg. Co.* is given in their bulletin DI-1. Design features for high reduction ratios, large tonnage, and better product quality are shown photographically and diagramatically. Gradation percentage charts are also provided.

Asbestos—A Matter of Time. (16mm color, sound; 20 min.) Produced in cooperation with Johns-Manville and filmed by Wilding Picture Productions, Inc., this new U. S. Bureau of Mines release is available for use in the United States only. Write the Bureau for more details on availability.

This new film lists the main area where asbestos is obtained and shows in particular the extraction and milling at Asbestos, Que. Surface mining operations—drilling, blasting, and removal of ore from the earth—are shown. Underground the block caving mining operations are depicted.

After scenes of processing techniques, the film describes the varied uses for this unusual mineral fiber.

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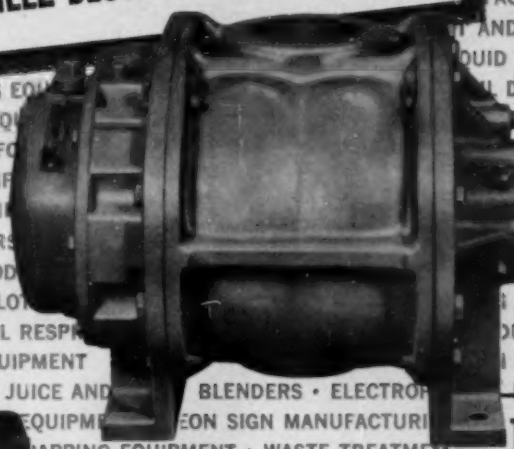
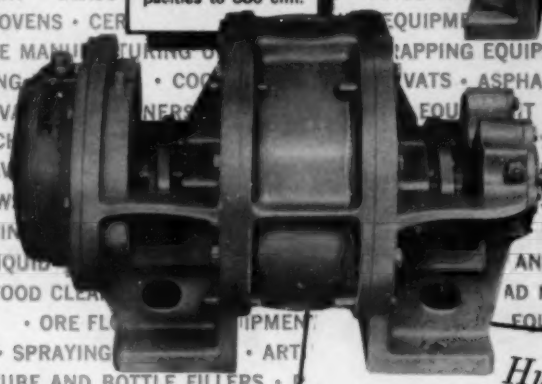
ROOTS-CONNERSVILLE BLOWERS & GAS PUMPS



TYPE XA GAS PUMPS

18 sizes for pressures to 6 psig; capacities to 880 cfm.



TYPE AF BLOWERS

18 sizes for pressures to 10 psig; capacities to 920 cfm. Available in vertical and horizontal construction.

Hundreds of manufacturers stake their product reputations on the dependability and durability of Roots-Connersville rotary positive blowers and gas pumps. Why? The "Roots" principle of rotary positive displacement provides: 1) controlled volume accuracy, 2) long life and low maintenance because of frictionless operation, 3) oil-free air because no internal lubrication is required, 4) flexibility because they adapt to any type of drive, plus 5) dependable Roots-Connersville technical service before and *after* installation.

Most major companies and hundreds of smaller ones find Roots-Connersville blowers and gas pumps obvious choices for both pressure and vacuum applications.

For full information about these small-capacity units, write for Bulletins AF-XA-360, AF-258 and XA-458.

The only manufacturer providing a full selection of rotary positive, centrifugal and Spiraxial® designs in air and gas handling equipment—

ROOTS-CONNERSVILLE BLOWER

DIVISION OF DRESSER INDUSTRIES, INC.

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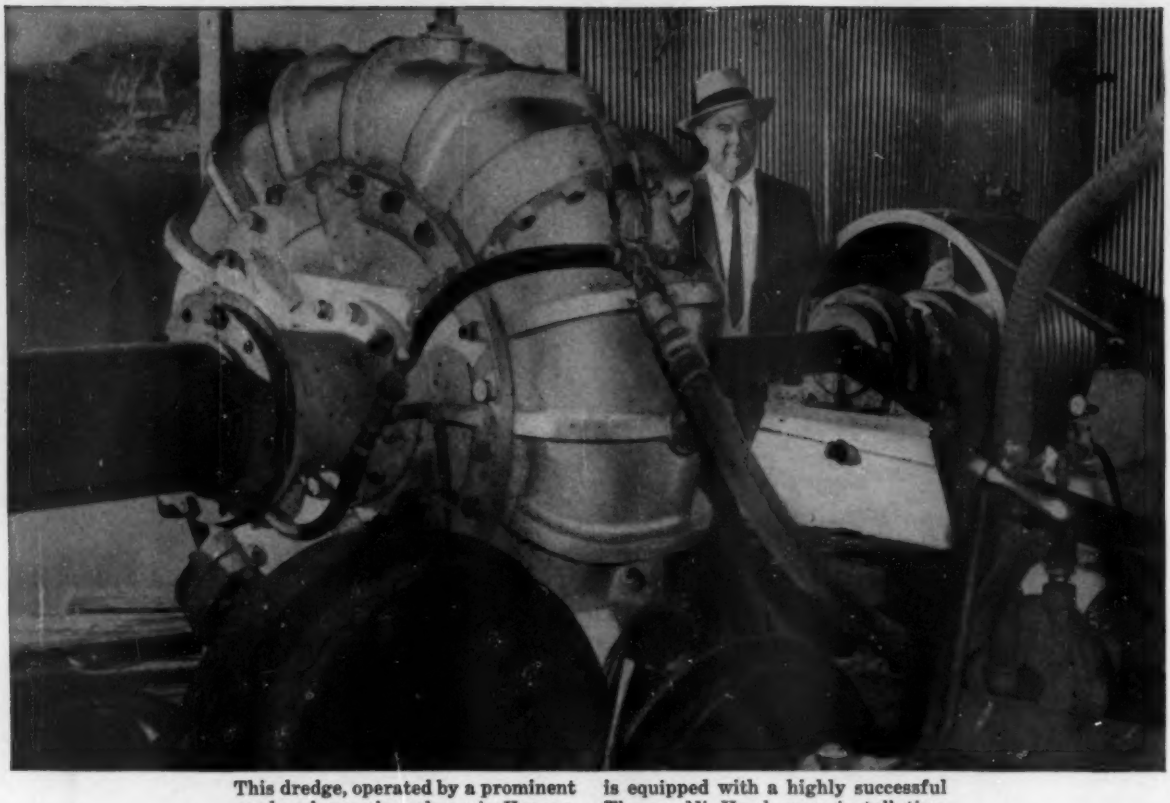

This dredge, operated by a prominent sand and gravel producer in Kansas, is equipped with a highly successful Thomas Ni-Hard pump installation.

Dredgers report Ni-Hard alloy pumps outwear others 4 to 6 times

From state after state come reports of the extraordinary service life of Thomas Ni-Hard pumps, made by Thomas Foundries, Inc., Birmingham, Alabama.

A West Virginia sand and gravel producer, for example, reports, "Since 1953, we have used only two Ni-Hard shell liners . . ."

A New Jersey company formerly replaced parts every 2 to 3 weeks . . . now says, "Today, we get approximately a year's service . . . a lifesaver."

From Nebraska: – ". . . after almost two years of pumping has required no repairs, major or minor."

From Arkansas: – ". . . by far the most efficient and economical pump we have ever used, our 40-year records prove."

From these reports, it's easy to see that *longer pump life means lower operating costs!*

And a large part of the credit for the outstanding durability of Thomas Pumps goes to Ni-Hard* nickel-chromium cast iron.

This alloy is the most abrasion resistant of all commonly used cast materials, out-lasting many 4 to 6 times . . . regularly outwearing manganese steel in pump service.

What's more, Ni-Hard alloy has demonstrated remarkable impact resistance . . . being widely used for drop balls, crusher linings, and for many other severe applications. In impellers, casings, linings, and other parts for pumps, Ni-Hard alloy has virtually eliminated cracks or impact erosion caused by gravel and rocks.

If severe wear is running up your operating costs – it will pay you to find out what Ni-Hard alloy can do. Inco's booklet, "Engineering Properties and Applications of Ni-Hard" gives you essential details, and Inco's "Ni-Hard Buyers' Guide" lists authorized producers throughout the country. Write us for your free copy.

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THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N.Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Overall U. S. Mineral Value Up in 1959, Metals Off

The value of the nation's mineral production climbed to about $17.14 billion last year, an increase of some $600,000 over 1958 according to preliminary USBM estimates. Strikes held metal output down but increased mining of uranium, bauxite, and molybdenum helped offset losses in iron ore, copper, lead, mercury, and others. Dollar values by groups were as follows: fuels, $11.9 billion; metals, $1.55 billion; non-metals, $3.69 billion.

Canadian Mine Production Set Record

Output of minerals in Canada was up almost 14 pct over 1958, setting a new high of more than $1.9 billion. According to the Dominion Bureau of Statistics, uranium was the top metal at a value of over $324 million, but gains were also shown in copper, iron ore, and nickel. Fuels were valued at $540.1 million; metals at $1.359 billion; and non-metals at $176 million.

DeBeers Can Make Synthetic Diamonds

The DeBeers diamond trust has announced development of its own process for making synthetic industrial diamonds. Commercial production of the stones is technically and economically possible, says DeBeers, but decision to go ahead would hinge on consultation with Belgian Congo Diamond Mining Co., world's largest producer of natural diamonds. . . . General Electric Co., first to announce successful diamond manufacture, followed up the DeBeers announcement with the statement that it is now capable of making synthetic stones for use in metal bonded grinding wheels. First stones made by GE could be used only in vitreous and resin wheels.

Mine-Mill, Kennecott Agree on Contract

An 18-month pact calling for a package wage and benefit hike of 22.3¢ an hour brought to an end the four-month-old strike at Kennecott Copper Corp. by the International Union of Mine, Mill, and Smelter Workers.

Cerro's Rio Blanco in First Stages

Cerro de Pasco Corp. is presently tackling the problem of engineering a 3½-mile development tunnel beneath the copper orebody of its Rio Blanco property near Santiago, Chile. Some 116 million tons of 1.6-pct ore have been indicated in a preliminary drilling program, and the company is studying the feasibility of erecting a smelter in addition to building mining and milling facilities. Cerro has estimated the cost of the project at aboout $70 million—$90 million if the smelter is included.

Zinc Sales Up, Price Climbs

Increased demand for galvanizing metal has put zinc in its best market position in many months. Settlement of the steel strike was a major factor in the upstep. In addition, use of high grade metal for die-casting has been strong in recent months and lately has shown increases in the automobile and appliances field. Price of prime western grade metal rose a half cent to 13¢ on the trail of the increased buying.

MINING engineering REPORTER

Nickel Use Expected to Rise

Pointing to expected rises in automobile and steel industry output in 1960, the BDSA predicts nickel consumption will climb sharply . . . . International Nickel's Thompson mine in Manitoba will be a new producing source of the metal this year. Slated to be the second largest world nickel producer, the operation should attain capacity output in 1961, perhaps even late this year . . . . Shipments of nickel from the Nicaro plant in Cuba have halted pending clarification of new tax laws in that country.

Aluminum Price Raised to 1957 Level

In a move laid to stronger world aluminum prices, domestic producers of the light metal raised their quotations for pig by 1.3¢, to 26¢ per lb—the August 1, 1957, price which dropped in April 1958 . . . . BDSA expects aluminum shipments to consumers to increase some 10 to 15 pct during 1960.

Jeffrey Mine Sets Safety Record

Canadian Johns-Manville Co.'s Jeffrey mine has tallied up more than 2 million manhours without a lost-time accident. Located in Asbestos, Que., the Jeffrey is the world's biggest asbestos producing mine. At 11 months Canadian asbestos shipments were up 13 pct over 1958.

Uranium Notes

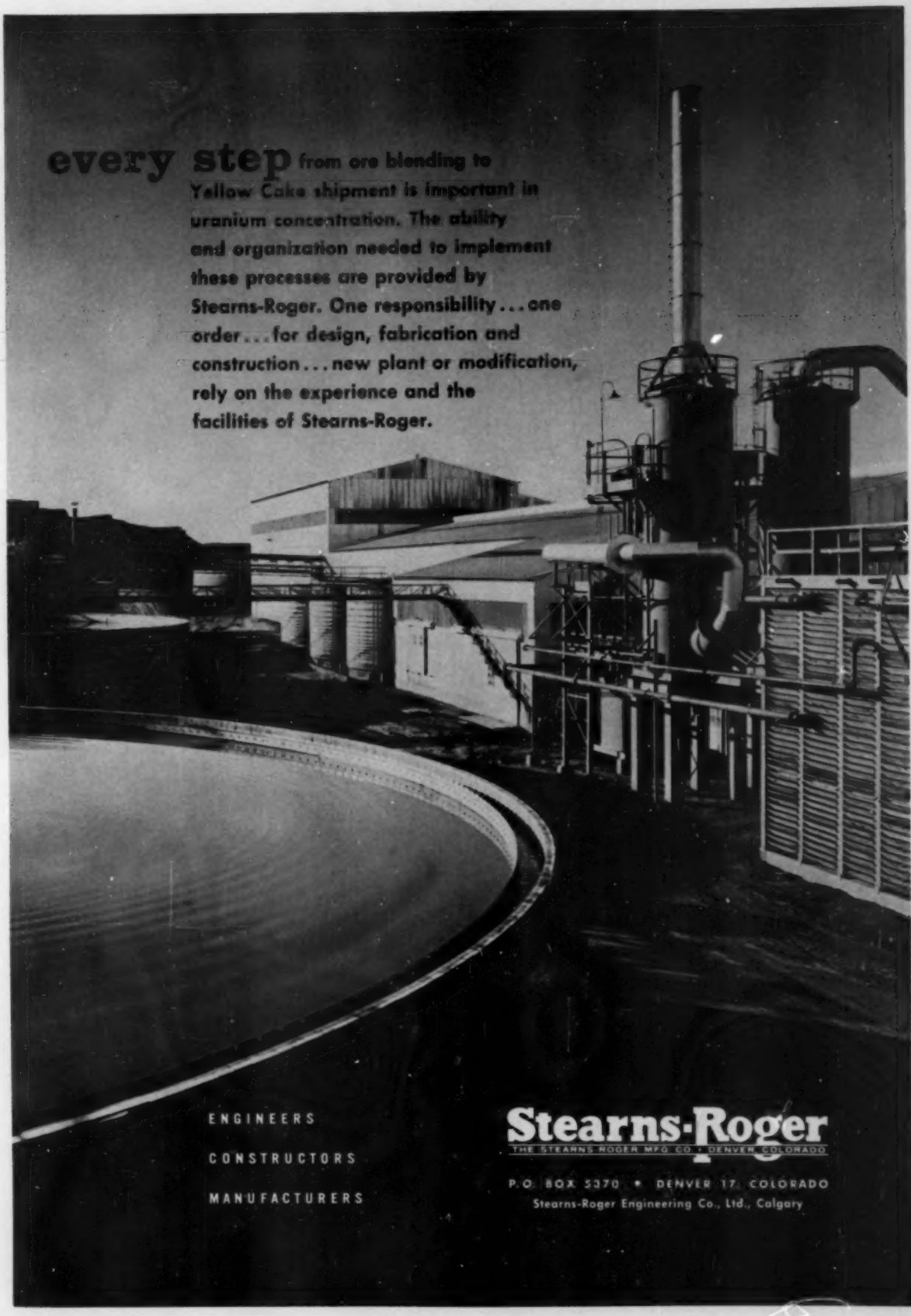
Susquehanna-Western Inc. has anounced plans for a prosoped uranium ore processing plant to be erected near Falls City, Tex. . . . Cotter Corp. of Sante Fe, N. M., has signed a uranium purchase contract with the AEC which will permit conversion of the company's 50-tpd pilot plant to a full-scale 200-tpd mill . . . . A uranium purchase agreement between the AEC and Anaconda Co., operator of the Bluewater, N. M., mill, extends the termination date of Anaconda's contract. The agreement, originally set for expiration on March 31, 1962, will now run until December 31, 1966, as part of a stretch-out program for domestic production. The mill work will be reduced from seven days to six.

Lead Price Off One Cent

The price of lead suffered two half-cent cuts in the space of a week, putting the metal at 12¢ per lb. Buying had been slow and stocks in the hands of producers remained large . . . . Overall consumption was on the upswing last year, increasing by 11.6 pct to some 1.1 million tons, according to the Business and Defense Services Administration. Improved automobile output expected this year should strengthen the lead market through increased use by battery makers, biggest domestic lead consumers.

Copper Research Promotion Group Formed

Copper Products Developments Assn. Inc., an organization designed to advance the use of copper and copper products through sponsored research projects has been chartered by six leading copper producers: American Metal Climax Inc., American Smelting & Refining Co., Anaconda Co., International Nickel Co. of Canada Ltd., Kennecott Copper Corp., and Phelps Dodge Corp.


every step from ore blending to Yellow Cake shipment is important in uranium concentration. The ability and organization needed to implement these processes are provided by Stearns-Roger. One responsibility... one order... for design, fabrication and construction... new plant or modification, rely on the experience and the facilities of Stearns-Roger.
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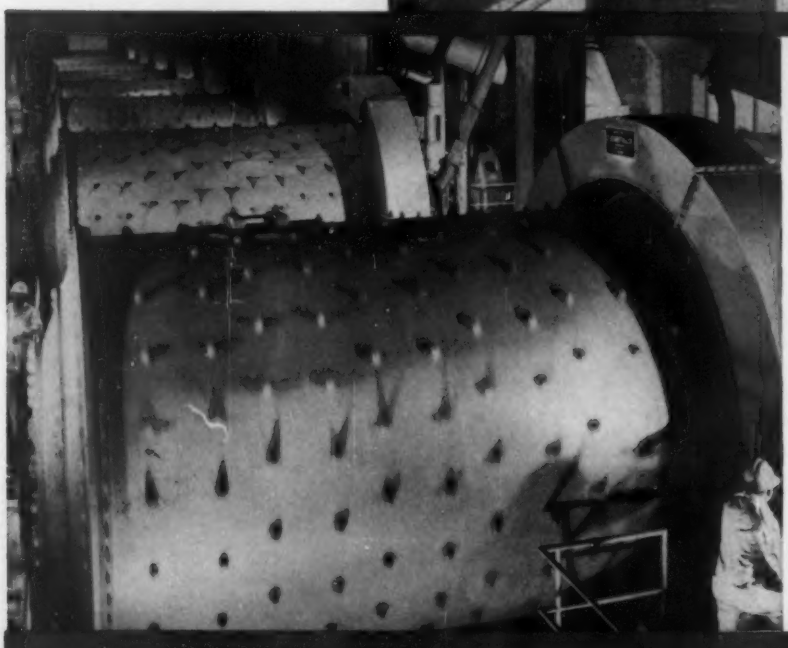

grinding mills

Ball mills, tube mills and multicompartment mills—open or closed circuit—wet or dry grinding. Also airswept for grinding and drying. Over 1250 Smidth Rotary Kilns and over 5000 Grinding Mills supplied all over the world.

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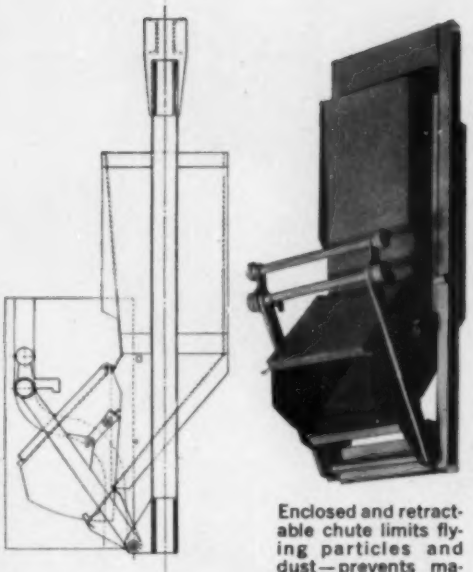
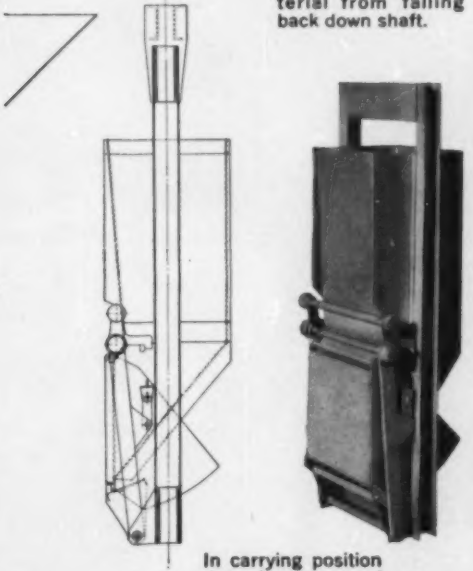
Door pivots from top in new front discharge skip

ACTIVATED BY TOGGLE LINKAGE SYSTEM



Enclosed and retractable chute limits flying particles and dust—prevents material from falling back down shaft.



In carrying position door is squeezed closed against rubber seal—locked in position—safety hook locks dump roller in position.

Lake Shore's new front discharge skip is similar in general construction to the Anaconda and other front dump skips. The unit differs in that the door pivots from the top and is actuated by a toggle linkage system that gives the same desirable door operating features as Lake Shore's famed "Jeto" Skip. The door is closed against the rubber seal by means of the toggle linkage and mechanically locked in position. This eliminates all possibilities of spillage and makes the skip completely watertight. The main dump roller is locked in position by a safety hook actuated by another pair of rollers above the main dump rollers. This insures positive locking and complete protection against possible opening in the shaft.

An enclosed chute extension from the skip in the opened position, limits flying particles and dust problems during dumping. Also, a retractable chute extends over the bin during dumping, thus preventing material from falling back down the shaft. On average sizes the skip can dump within three feet vertical travel after the skip has entered the dump scrolls. This is possible because during the major portion of the door opening the pressure of the load against the door helps it to open.

This latest development by Lake Shore provides the mining industry with a clean, fast dumping front dump skip that produces minimum reaction on the headframe while dumping.

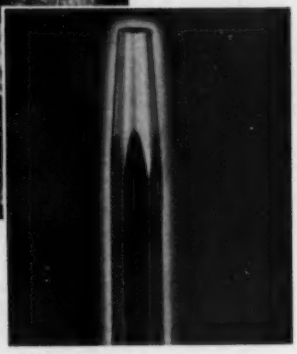
Patents Pending

LAKE SHORE, Inc.

IRON MOUNTAIN, MICHIGAN

VACUJET

Drilling Team cuts roof bolting costs 3 WAYS!



1. VACUJET DUSTLESS STOPER CUTS OPERATING COSTS

Here's a stoper that includes its own built-in dust-removal system—gives you fast, clean drilling without any additional vacuum equipment. An ejector jet built into the drill backhead creates a vacuum that pulls all dust and cuttings down through the hollow drill steel and ejects them under positive pressure to any convenient dust collector. Even a simple canvas bag, as shown above, serves the purpose.

Because of its highly efficient ejection system, the Vacujet Stoper uses 15% less air and provides greater drilling power and speed. It's easier to set up and use, too. There are only two hose connections to the drill—the compressed air line and the dust discharge hose.

If you haven't tried the Vacujet, you don't know how simple and economical dry dustless drilling can be. Ask your I-R engineer for complete information, or send for Bulletin 4195.

2. CARBURIZED DRILL STEEL CUTS ROD COSTS

Ingersoll-Rand *carburized* drill steel is specially treated to provide exactly the right combination of hardness and core toughness to withstand millions of impacts without molecular fatigue. On job after job, these super-steels have outlasted ordinary alloy steel rods by two-to-one! This means less steel to handle—less time out for rod replacement. Rods are easy to recondition, too—simply cut off shank or grind Class B taper for bit end.

3. NEW "one-use" CARSET BITS CUT BIT COSTS

Here's a long-life, heavy-duty tungsten carbide insert bit that can be drilled to destruction *without any resharpening*. One Carset bit will outlast 16 to 20 "one-use" steel bits—at a saving of up to $1.60 per bit cost alone. More important, the time saved changing steel bits is converted into drilling time. On typical applications, "one-use" Carset bits are drilling 235 ft. where steel bits lasted 12½ ft.—and 350 ft. where steel bits were completely used up in 17 feet of drilling. Available in 1½" and 1⅜" sizes, with Class B taper connection. No shims needed.

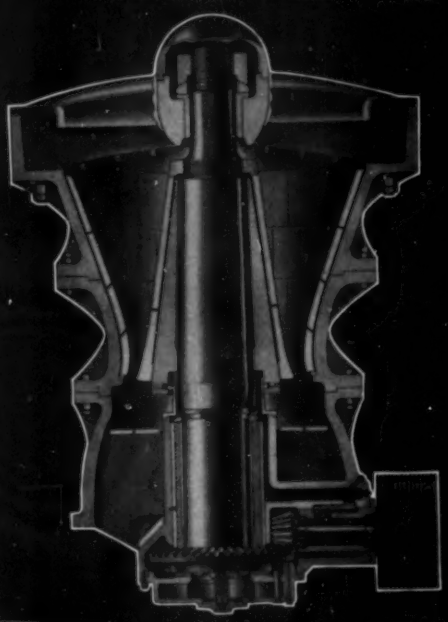
Ingersoll-Rand

3-970

11 Broadway, New York 4, N. Y.

A CONSTANT STANDARD OF QUALITY IN EVERYTHING YOU NEED FOR DRILLING ROCK

TC GYRATORY CRUSHERS



Traylor-made for primary reduction

Traylor engineers are the world's largest builder of giant 60" Gyratory Crushers. Here are some of the reasons the Traylor TC Gyratory Crusher is so much in demand:

- A straight line bar type spider, of heavy construction—simple but strong.
- Traylor original, self-tightening, bell head and curved concaves.
- The Traylor patented dust seal. A practical and efficient device for excluding foreign matter from the lubrication chamber.
- A positive outside automatic lubrication system.
- Bronze bushed eccentric bearing with pressurized lubrication.

Visit us at Booth No. 56 at the CRUSHED STONE SHOW, Feb. 22 thru 24, Conrad Hilton, Chicago

. . . made in 7 sizes with feed openings 20" to 60" and capacities from 1,240 to over 32,000 tons per eight hour day are in use by many leading producers throughout the world.

For specifications and capacities, send for Traylor Bulletin No. 1126.

Shown above a 54" TC Gyratory Crusher in a portland cement plant.

GYRATORY CRUSHERS • JAW CRUSHERS
Traylor
ROTARY KILNS • BALL MILLS • APRON FEEDERS

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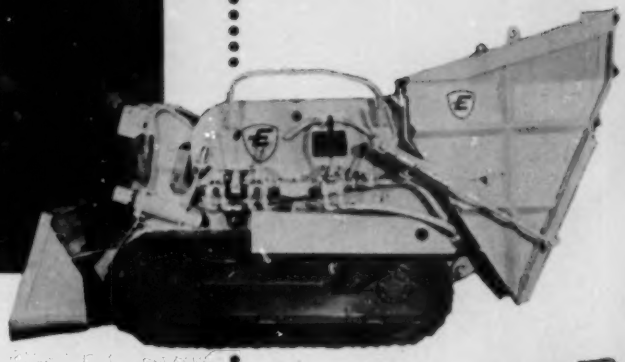

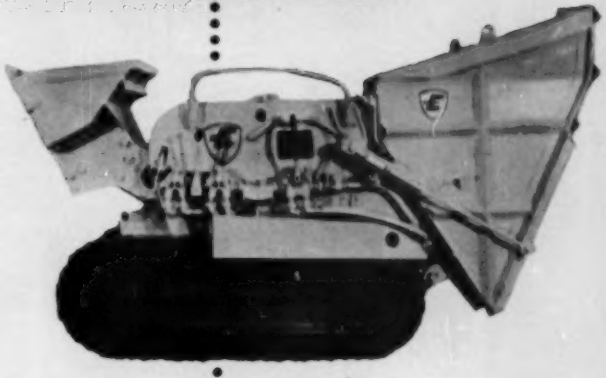

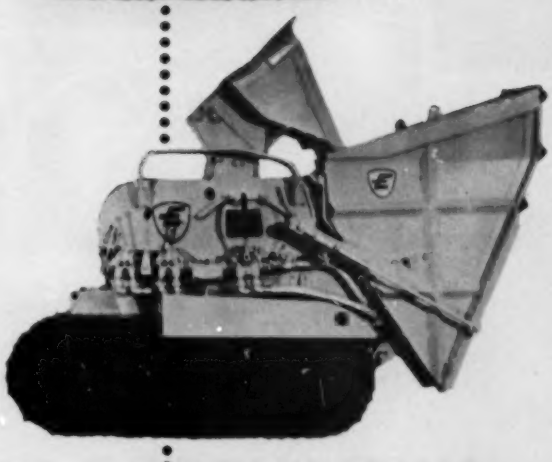

GREATER PRODUCTION WITH EIMCO 631

. . . crawler mounted hopper loader with greater capacity

Latest addition to the famous 630 series of compressed air activated, crawler mounted equipment, with a greater hopper capacity of 45 cubic feet. With an additional 5 cubic feet carried in the bucket, a payload of three tons (50 cubic feet), can be easily handled. The 631 will also be available for AC operation.

The Eimco 631 is self-loading, capable of both loading and carrying material. It is the answer to many and varied problems of developing and production-loading in stopes, drawpoints and other such areas.

Features include special long tracks for maximum stability and ground contact area; a positive semi-automatic hold-device, for holding loaded bucket in carrying position; heavy-duty and removable hopper with full opening door; improved, heavier equalizer bar; new, improved trunnions and brackets and additional track rollers for a crawler base capable of easily carrying these heavier loads.

Contact the nearest sales office or write The Eimco Corporation, P.O. Box 300, Salt Lake City 10, Utah, for all details.

"ADVANCED ENGINEERING AND QUALITY CRAFTSMANSHIP SINCE 1884"

THE EIMCO CORPORATION

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MINING EQUIPMENT DIVISION

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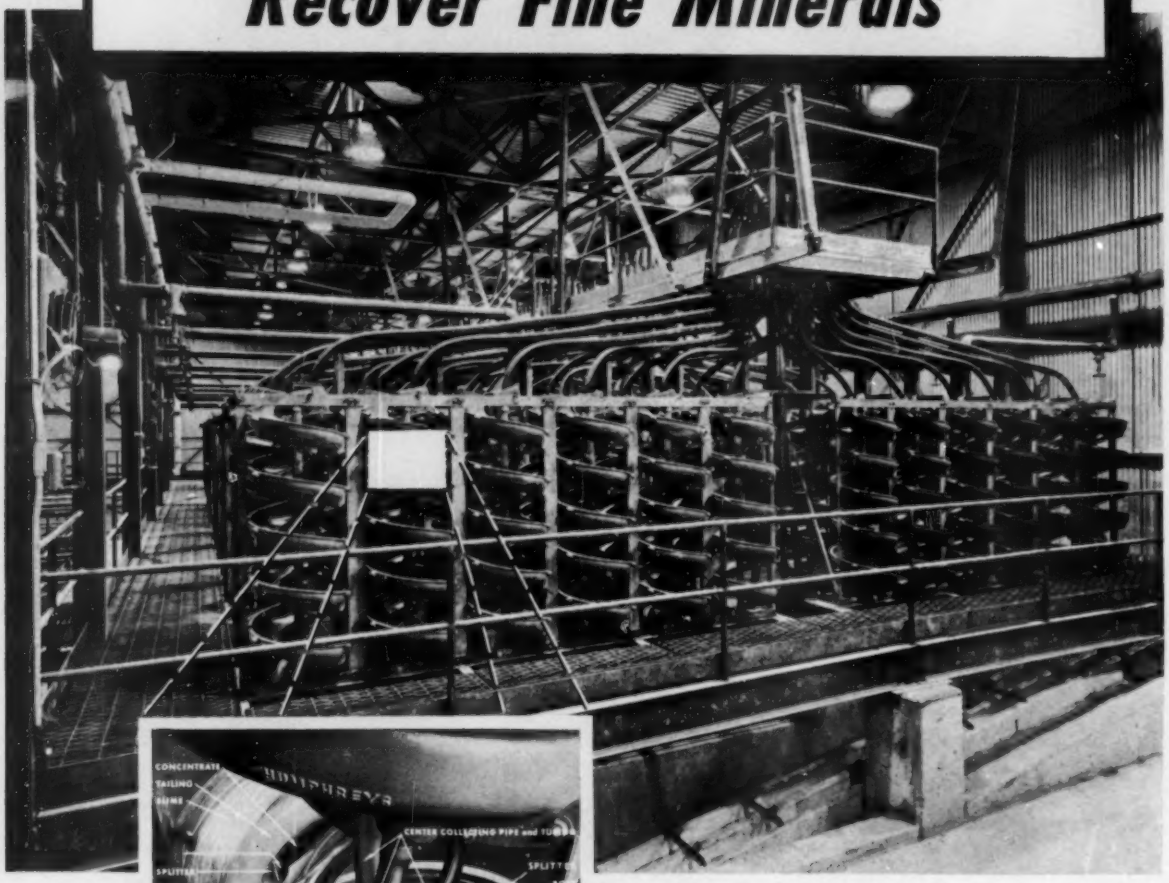
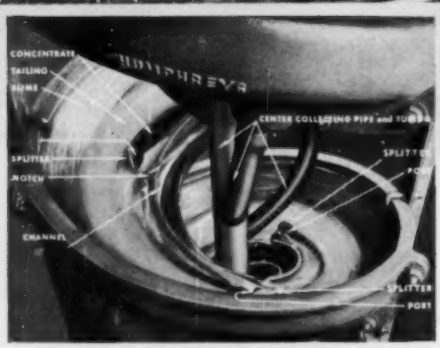
Recover Fine Minerals





A metallurgical testing laboratory is maintained in Denver, Colorado by the Humphreys Engineering Co. Results to be realized in a full-scale plant can be determined by testing a representative sample of your ore.

Our engineers will be glad to work with you.

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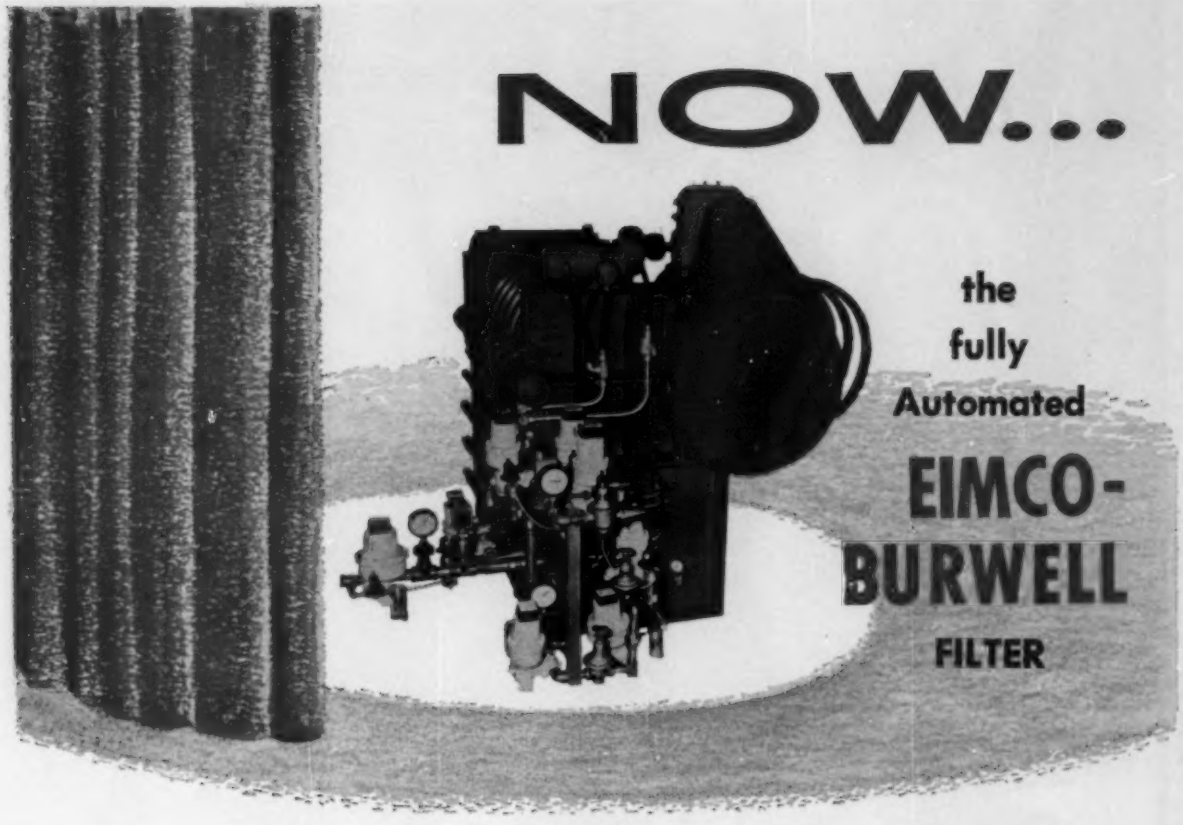

Starts it's own Cycle ...Completes Cycle ...Starts Over – Automatically!

Another Eimco achievement in the development of equipment for liquid-solids separation is the Eimco-Burwell filter shown above. Built for a separation process involving the recovery of a valuable metal, this is the first plate and frame filter capable of completely automatic operation.

The filter is equipped with an electric timing control circuit and all auxiliaries for automatic operation on a multi-cycle basis. No operator attention is required once the controls are set. Opening and closing of frames . . . fill . . . wash . . . blow . . . rotation — all fully automatic.

The automated Eimco-Burwell represents the end result of thousands of hours of development work by Eimco engineers. It represents, too, the elimination of high labor costs commonly associated with the operation of plate and frame filter presses.

The Eimco-Burwell is unequalled by any filter for washing out the highest percentages of soluble values from the cake, or for producing a filtrate containing an absolute minimum of contaminants. It can handle materials of widely varying characteristics, including viscous slurries.

For more details, get in touch with the Eimco representative in your area. Or, write the Eimco Filter Division for Bulletin F - 2052.

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THE EIMCO CORPORATION

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FILTER DIVISION
634 SOUTH 4TH WEST
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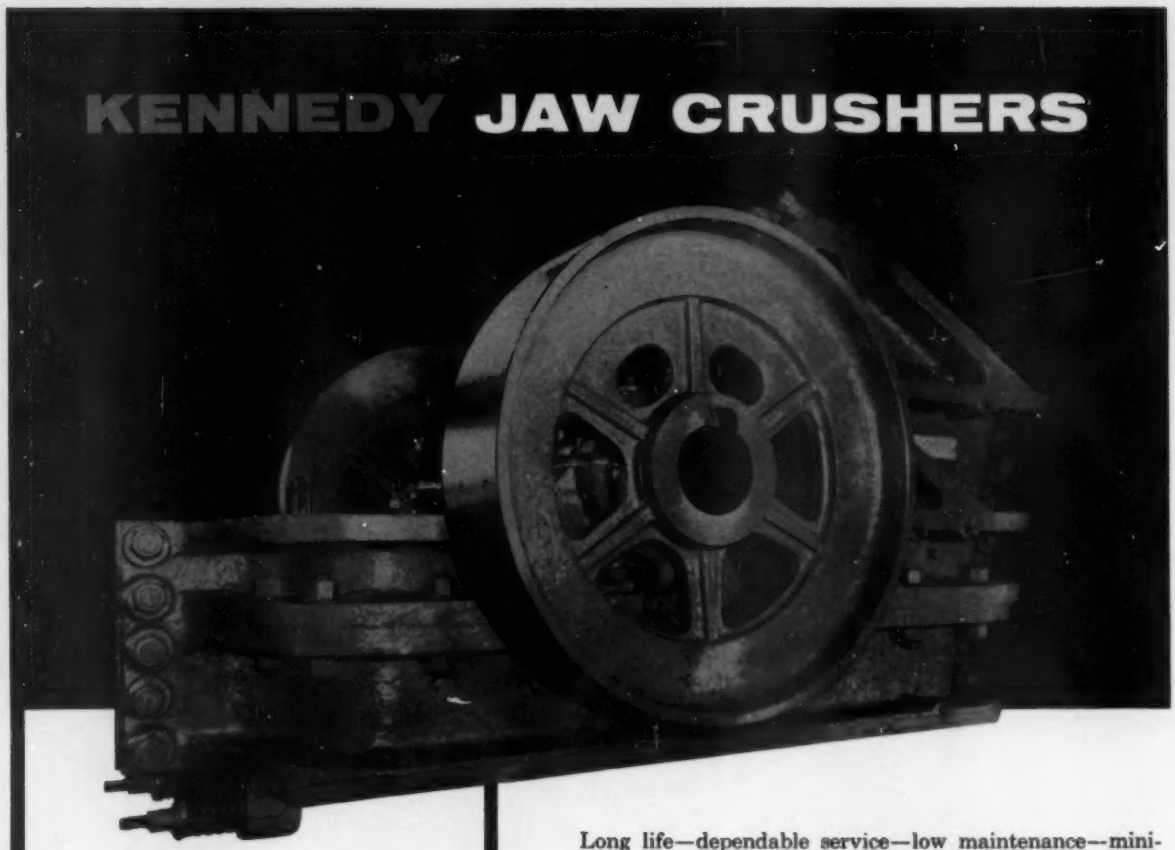
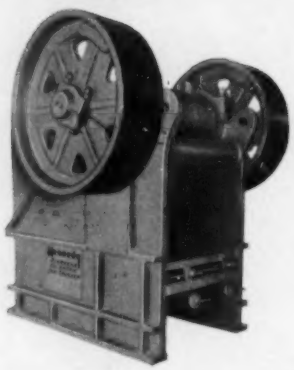
RESEARCH AND DEVELOPMENT CENTER
301 SO. HICKS ROAD, PALATINE, ILLINOIS

KENNEDY JAW CRUSHERS





The KENNEDY Overhead Eccentric Jaw Crusher features a massive, one-piece, arc welded steel plate frame, and is available in standard sizes from 10″ x 36″ to 36″ x 42″.

Long life—dependable service—low maintenance—minimum power—high production—make KENNEDY Jaw Crushers the first choice of all who buy because of proven performance and low year-to-year cost.

Exclusive features of the KENNEDY Jaw Crusher

- Cast Meehanite or steel frame.
- Counterbalanced flywheel lifts pitman at bottom of stroke. Makes starting easier.
- Split frame design distributes stresses evenly. There can be no failures at the corners.
- No loss of power due to "weaving" and misalignment common to ordinary 4-piece crusher frames.
- Rocking toggles require no lubrication.
- Each jaw bears exactly half the load because both are mounted at the same angle. No power is wasted in lifting the charge.
- Jaw plates are interchangeable and reversible. Shaft is integral with swing jaw.
- Available in standard sizes from 7″ x 10″ to 66″ x 84″.

Send for complete information on KENNEDY Crushers.

KENNEDY VAN SAUN

MANUFACTURING & ENGINEERING CORPORATION

405 PARK AVENUE, NEW YORK 22, N.Y. • FACTORY: DANVILLE, PA.

Primary & Secondary Gyratory Crushers • Jaw Crushers • Roll Crushers • Impact Breakers • Hammer Mills • Rod & Ball Mills • Kilns • Dryers • Screens • Mechanical & Pneumatic Conveyors • Complete Crushing, Lime, Cement & Carbon Paste Plants. KENNEDY Research & Testing Service.

5 reasons why Atlas Copco's "TIGER" is best for stoping and all short-hole drilling!

(1) It's fast and easy to handle!
(2) It's easy collaring, with little recoil!
(3) Features a retractable air leg!
(4) Convenient controls, automatic back head!
(5) Operates on single air supply!

Here's the TIGER—a new, fast, compact rock drill with power and stamina to meet toughest drilling requirements! Its high percussion rate not only speeds penetration, but at the same time cuts recoil to a minimum. With controls conveniently located, collaring is unusually easy.

What's more, the automatic back head prevents dry collaring. Flushing water actually flows before drilling starts. And, the Tiger's "constant blowing" provision sends air through the machine the instant pressure is turned on, keeping water and cuttings from the rotation chuck.

There's still another "plus"—the Tiger's exclusive integral type pusher leg, with retractable piston rod. Operates on a single air supply!

This isn't the whole story by any means. For more facts about the amazing new Tiger rock drill and how it can speed *your* drilling, call your nearest Atlas Copco representative. Or, write to us at Dept. ME-10.

Atlas Copco

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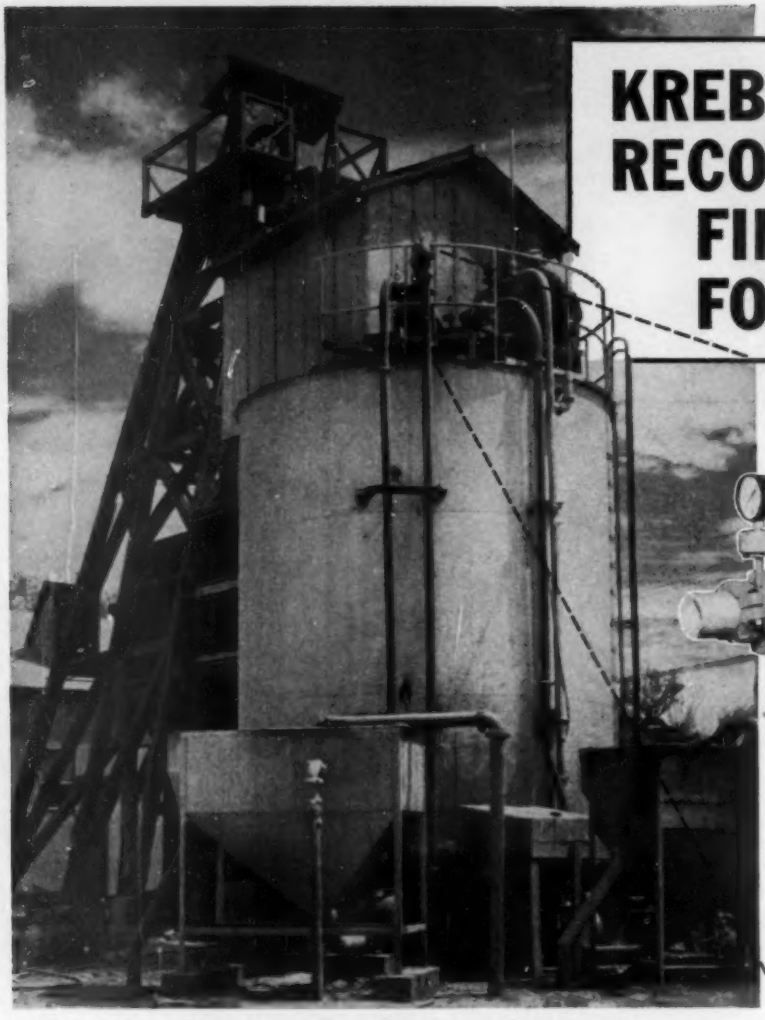
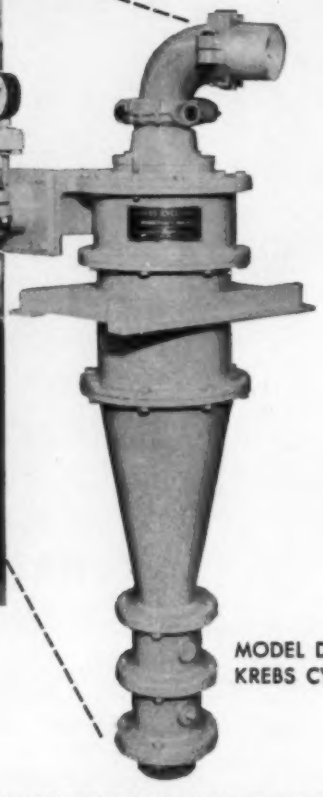
KREBS CYCLONES RECOVER 80% OF FINE TAILINGS FOR MINE FILL



Installation at Banner Mining Company Copper Operation near Tucson, Arizona



MODEL D10B
KREBS CYCLONE

EXCEPTIONAL WEIGHT RECOVERY FROM TAILINGS OF 29% SOLIDS CONTAINING 47% MINUS 325 MESH MATERIAL!

GOOD PERCOLATION AND FAST SET! Fresh pours drilled from after 4 hours... ore blasted down on fresh fill the following shift.

Results for the above application were closely predicted in advance from test work performed in our Pilot Plant. Units were recommended that would meet the objectives of high weight recovery from a fine product in an area where water was scarce.

There are Krebs Cyclones of the correct size and design available for your specific objectives.

PERFORMANCE CHART OF 2 KREBS D10B CYCLONES AT BANNER MINING COMPANY

	FEED	OVERFLOW	UNDERFLOW
% Solids	29.0	9.0	74.0
SIZING—	FEED	OVERFLOW	UNDERFLOW
% +100	4.9		6.2
+150	10.2		13.0
+200	12.7		16.2
+325	25.2		32.2
-325	**47.0**	**100.0**	**32.4**

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REAGENT NEWS

"ore-dressing ideas you can use"

SUPERFLOC 16 Flocculant reduces thickener overflow loss by 92.2%...*

recovers many times its cost for Non-Metallic Mineral Producer

At this non-metallic mineral operation, loss of solids in the overflow of a 25′ diameter thickener averaged 19 tons per day. Addition of only 4 lb. per day of SUPERFLOC 16 Flocculant as a 0.1% water solution cut overflow losses to a record low of 1.5 tons per day. While specific gravity of the underflow dropped 10% (75% to 65%) with use of flocculant, there has been no decrease in the throughput and fluidity of thickener underflow is much improved. Values recovered are worth many times the $6.56 daily cost of SUPERFLOC 16.

Previous comparative mill tests showed SUPERFLOC 16 Flocculant to be more effective in cutting overflow losses than other flocculating agents and at ¼ the daily cost of less effective agents.

If you have not yet tested SUPERFLOC 16 Flocculant as a settling agent and filter aid, write our nearest office for a test sample and technical data on its use.

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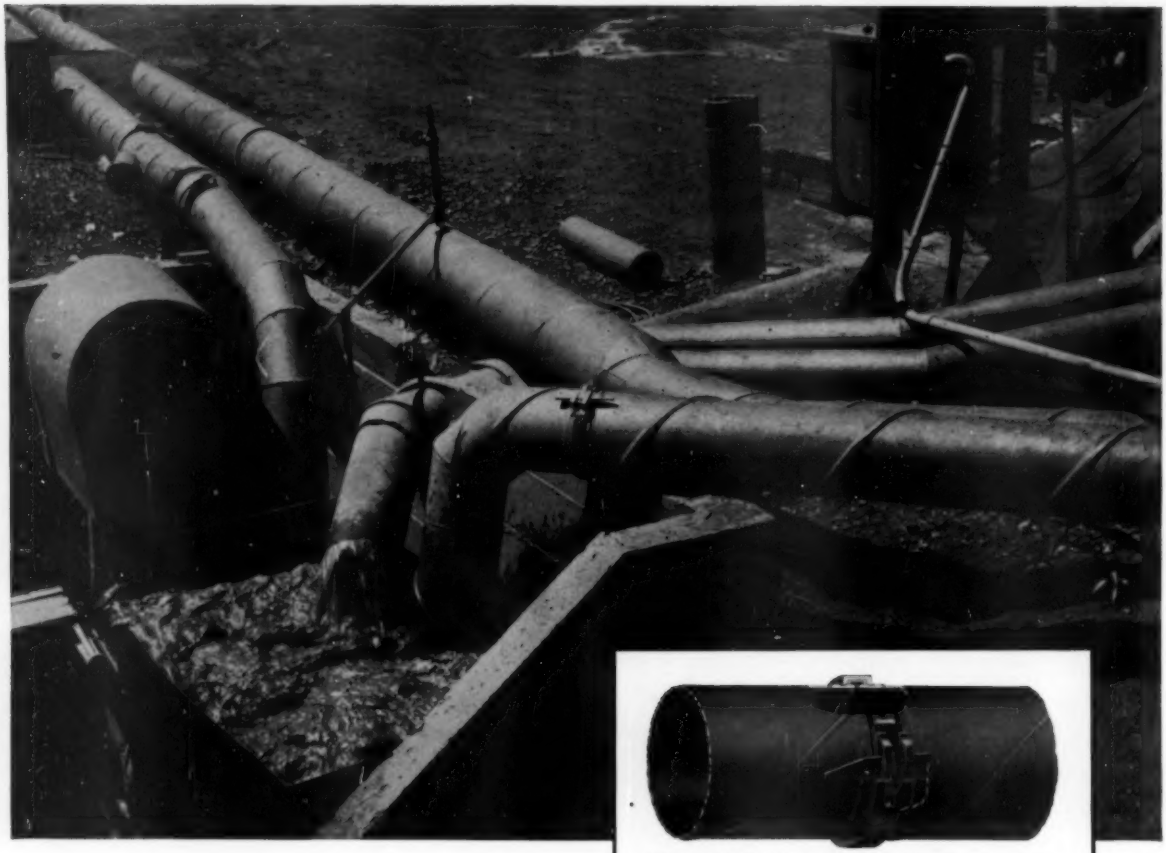
GET THE JOB DONE!



The NAYLOR Wedgelock coupling makes a positive connection—securely anchored in standard weight grooved ends. A hammer is the only tool required to connect or disconnect it.

When you need pipe lines for handling water, tailings or air, or for ventilating service—the combination of NAYLOR pipe and NAYLOR Wedgelock couplings can do the kind of job you need in 1960.

This distinctive lockseam-spiralwelded pipe provides light weight without sacrifice of strength and safety. It's easier to handle and install—particularly when you make connections with Wedgelock couplings.

If you're looking for faster installation and the kind of performance that spells economy, this NAYLOR combination is for you.

Write for Bulletin No. 59.

NAYLOR PIPE *Company*

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to create
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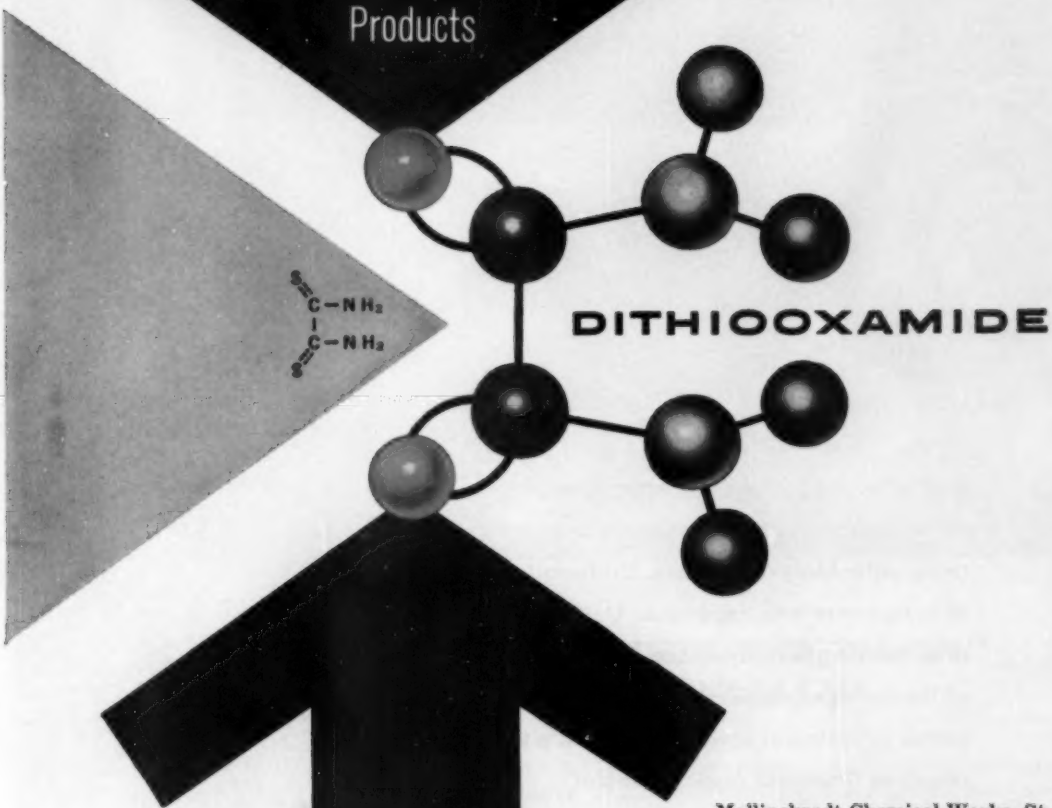

Mallinckrodt Chemical Works, St. Louis, Missouri, recently announced this new building block...a chemical that can go in many directions to create new and better products. For example, the manufacturer suggests applications for dithiooxamide and its derivatives in the fields of metal sequestrants, pigments, organic intermediates and plant growth regulators.

A new building block with many potentials ...and as with so many such chemicals, Sulphur is a key ingredient!

Our business is to produce Sulphur ...to keep adequate supplies on hand at our production units...to deliver it in solid form by rail, barge or ship; in molten form in trucks, tank cars, barges, or ships. All of the properties listed below can supply both solid and molten Sulphur.

TEXAS GULF SULPHUR COMPANY

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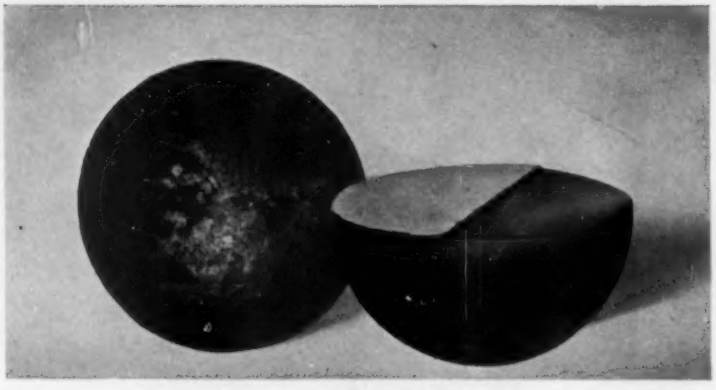

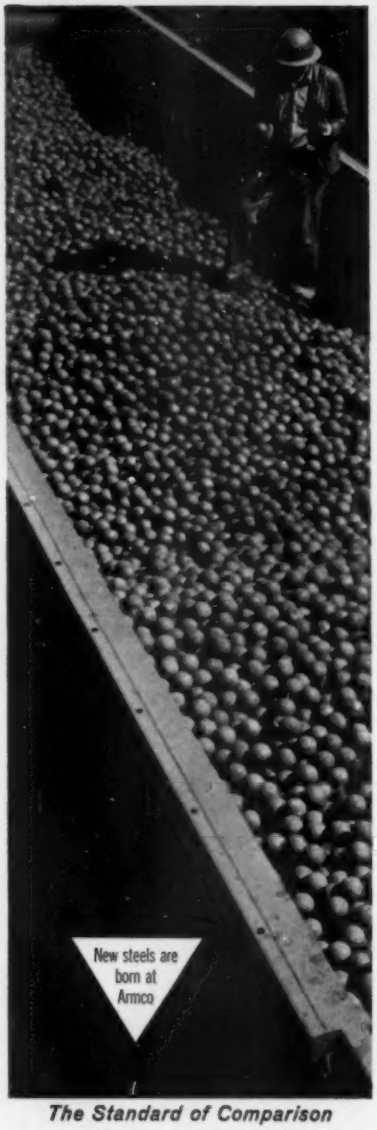

Ball after ball, charging after charging, carload after carload—uniformity is a sure thing with Moly-Cop Balls. Uniformity of toughness and hardness. Uniformity of fine, dense grain structure. Uniformity of longer service, less down time and better grinding at lower cost. That's the result of Sheffield quality control in alloying, forging and heat treating—from furnace to finished ball.

The Standard of Comparison Around the World

SHEFFIELD DIVISION

Sheffield Plants in Kansas City, Tulsa and Houston

ARMCO STEEL CORPORATION

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The Inquiring Mind at Oldsmobile

no. 9 OF A SERIES

OLDSMOBILE "TOES THE MARK" ... ELECTRONICALLY!

Oldsmobile Engineering Leadership sets the industry pace with a unique electronic wheel alignment device that dynamically computes "toe-in" measurements for precision steering and handling.

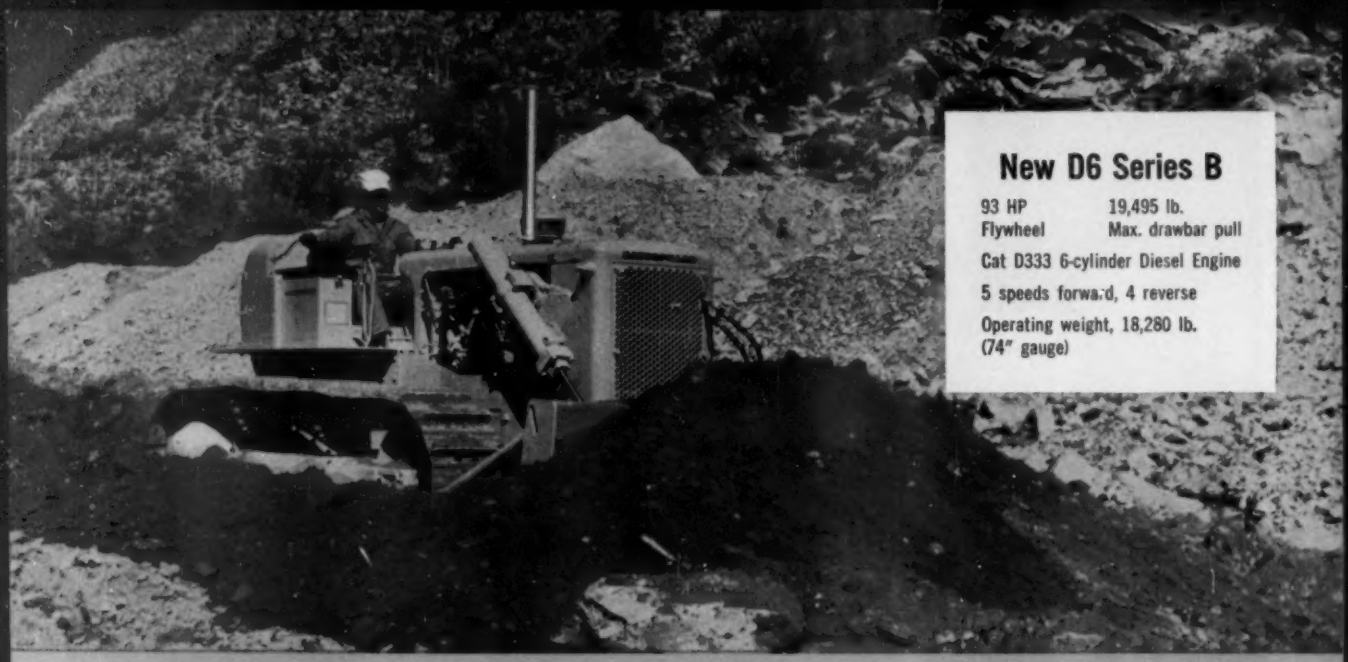
Handling and steering ease depend upon precise, minute measurement and control of front wheel alignment. Because wheels have a tendency to "toe-out" when in motion, they must be adjusted for a slight amount of "toe-in" to eliminate "wheel fight", wander and undue tire wear.

To meet the requirement of rapid, yet extremely accurate measurements on the production line, Oldsmobile engineers developed an electronic computor—a *linear-differential-variable transformer*—that dynamically and accurately measures the average amount of toe-in within .030 inches. As the car is brought into position, the wheels are rotated by rollers to simulate actual driving conditions and to eliminate errors caused by variations in tire run-out. By watching the visual gauges, an operator can quickly make the necessary adjustments to the steering linkage.

By using the most up-to-date electronic measuring techniques in engineering and manufacturing, Oldsmobile is able to offer safe, accurate steering and handling . . . a controlled, comfortable ride. Visit your local Oldsmobile Quality Dealer, take a ride in a '60 Oldsmobile and see why it's the value leader of its class!

OLDSMOBILE DIVISION • GENERAL MOTORS CORPORATION

OLDSMOBILE **Where Proven Quality is Standard!**



New D6 Series B

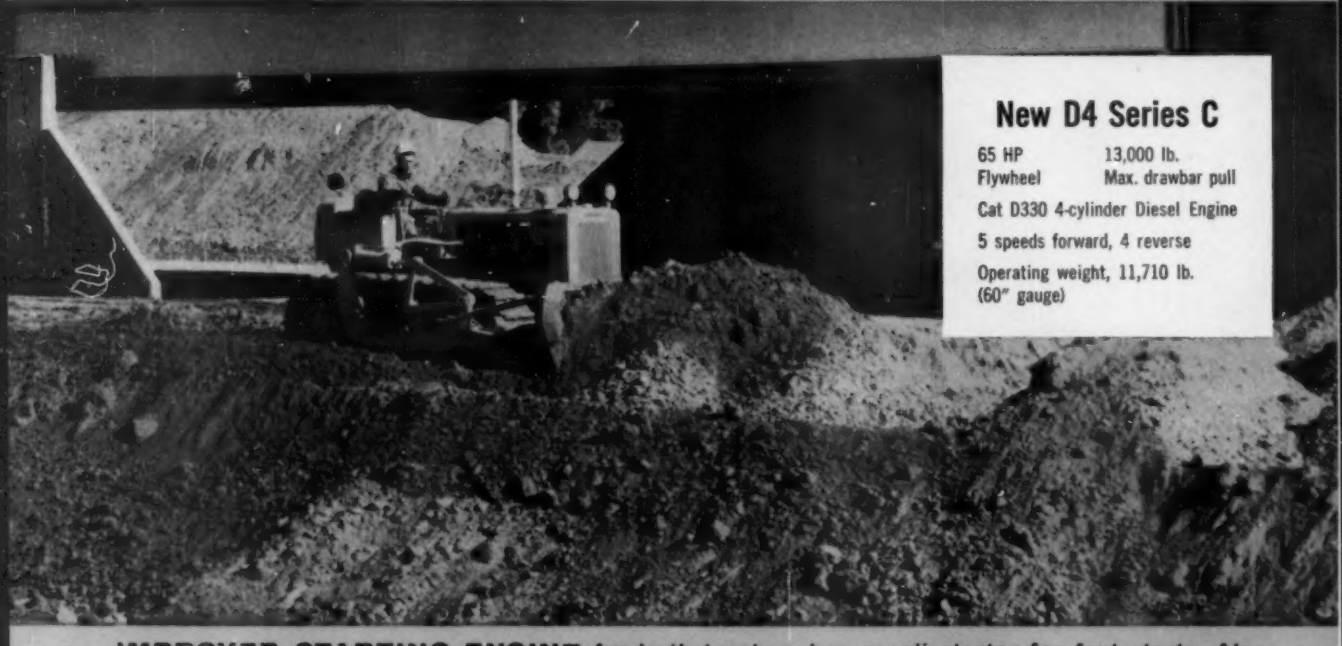
93 HP Flywheel — 19,495 lb. Max. drawbar pull

Cat D333 6-cylinder Diesel Engine

5 speeds forward, 4 reverse

Operating weight, 18,280 lb. (74" gauge)

RUGGED MATCHED ATTACHMENTS for the D6 and D4 include Bulldozers, Tool Bar, Scraper, Rock Rakes, Winches, K/G Blade, Rippers and others.



New D4 Series C

65 HP Flywheel — 13,000 lb. Max. drawbar pull

Cat D330 4-cylinder Diesel Engine

5 speeds forward, 4 reverse

Operating weight, 11,710 lb. (60" gauge)

IMPROVED STARTING ENGINE for both tractors has recoil starter for fast starts. Also 12-volt in-seat starting available. 24-volt direct electric starting optional.

CATERPILLAR ANNOUNCES the

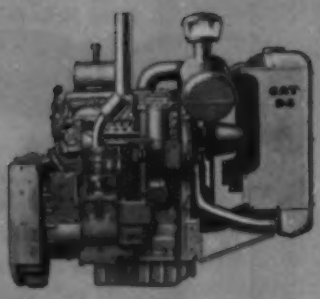
completely redesigned for faster and greater production

There's no time like now to upgrade your equipment spread. These two new tractors not only look different—they are different. Each, in its own class, answers your needs for higher production and greater operating economy. Some of their important new features are described on these pages. In addition to these improvements, each machine provides other famous Caterpillar features... the dry-type air cleaner,

D6 93 HP 6-cylinder Engine
Maximum drawbar pull, 19,495 lb. The D333 Engine provides power with dependability for a long life of economical operation.

New Caterpillar Diesel Engines deliver 25% more lugging ability

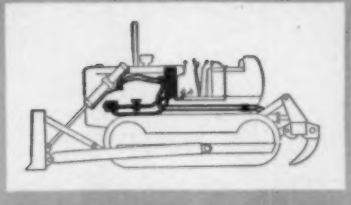
For the D6 and D4, two completely new Cat Diesel Engines. 25% more lugging ability. New compactness with new ruggedness. Famous Cat fuel injection pumps in new, easily serviceable housing. New direct acting governor that makes quick fuel adjustments, picks up loads fast. New, improved gasoline starting engine.



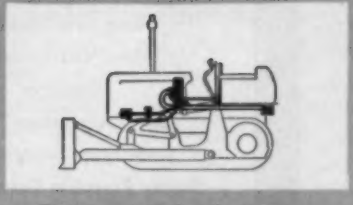
D4 65 HP 4-cylinder Engine
Maximum drawbar pull, 13,000 lb. New design of the D330 results in smooth, vibration-free performance in all speed ranges.

New integral hydraulic systems put more power where you need it

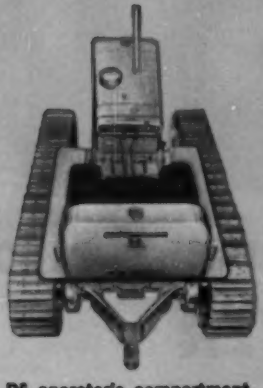
More work power at the tools—that's one of the big advantages of these new Cat hydraulic systems. Under-the-hood mounting of tank, pump and valves permits convenient routing of hydraulic lines to bulldozer or implement cylinders, frees front and rear for mounted equipment. Center-pivoted cylinder mounting on D6 gives increased blade lift/drop range for greater production. Hydraulic control system provides hand control for bulldozer and/or ripper, foot control for tilt cylinder on D6.



D6 Integral Hydraulic System
No. 165 Hydraulic Control for bulldozer
54 GPM Pump—1500 PSI
No. 143 Hydraulic Control for No. 6 Tool Bar
29 GPM Pump—1700 PSI



D4 Integral Hydraulic System
No. 143 Hydraulic Control with:
29 GPM Pump—1700 PSI for bulldozers
17 GPM Pump—1700 PSI for tool bars



D6 operator's compartment

New operator convenience and comfort in co-ordinated compartments

The cockpits are all new. Controls are co-ordinated to make one motion flow into the next, reducing hand movements and speeding every operation. Forward-reverse lever (new on the D4) is next to the operator's right hand to speed 'dozer cycle times. Short-travel transmission speed selector shifts gears easily, quickly. Boosters for steering clutches save muscles . . . increase efficiency.

D4 operator's compartment

New D4 Series C and D6 Series B Tractors

hydraulic track adjusters, lifetime lubricated track rollers, the oil clutch, the forward-reverse lever. Your Caterpillar Dealer will be happy to give you the complete facts about both the new D6 and the new D4 and demonstrate them on any of your jobs. The tougher, the better.

Caterpillar Tractor Co., General Offices, Peoria, Illinois, U. S. A.

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That's why—time and again—penetration rates go up and costs per foot of hole come down when Gardner-Denver drills and drill steel are used . . . why Gardner-Denver mine car loaders, drilling equipment, pumps and compressors are favorites among mining men everywhere.

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MINING engineering **DRIFT**

MEETINGS FOR SME'ERS IN 1960

From the view point of planning, the 1960 Annual Meeting is water under the dam. Meeting planning starts months or years ahead and Society officers, Local Section members and officers, and your SME staff are already looking ahead to 1961 and St. Louis.

What then about the balance of 1960? SME members can set their sights on regional and Local Section meetings from St. Louis to College, Alaska. For your information—and plans:

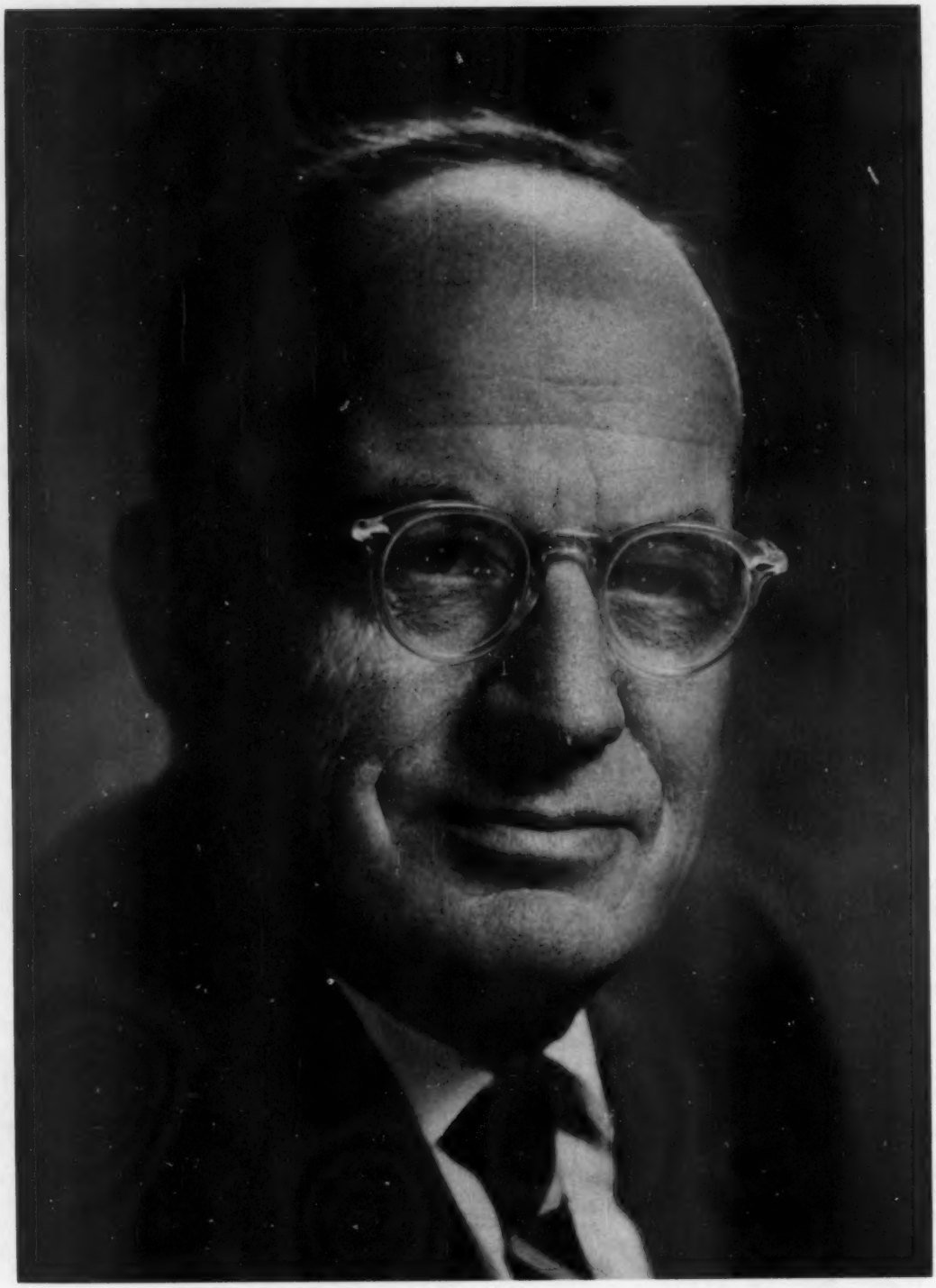
- The AIME Alaska and Southwestern Alaska Sections with an assist from the University of Alaska and Yukon Section, CIM, are holding the annual Alaskan Mining, Minerals, and Petroleum Conference in College in April. A major event for our 49th state, this year's program is sparked by need for economic development of this potentially rich area.
- SME'ers in the Southwest will convene in Los Angeles in April for the AIME Pacific Southwest Regional Metals and Minerals Conference.
- Also an April event is the Pacific Northwest Regional Conference being held in Portland, Ore., this year.
- Uranium miners, millers, and all interested parties will trek to Moab, Utah, in May when the AIME Uranium Section holds its annual symposium.
- Moving on toward fall, September has been set for a joint meeting of the SME Coal Division and the St. Louis Section in St. Louis—a technical program and field trip plans are well launched.
- The Utah Section is host in October for the AIME Rocky Mountain Minerals Conference, a meeting that was scheduled at least two years ago!

Not all SME members, by any means, will be able to attend all these meetings, but the locales—from East to West—afford members the opportunity of attending at least one—that nearest home or en route.

Preprints Are Available

Page 178 of this issue carries a listing of SME Annual Meeting Preprints that were available as the magazine went to press. Future issues will carry an additional list as more papers become available. For your convenience, the list has been grouped according to subject matter, with the author's name printed first. Read the instructions for ordering carefully—proper adherence to the procedure makes it possible to expedite your order and get the Preprints to you quickly.

The staff would like to ask that coupons not be used for requesting tearsheets of articles or Transactions papers appearing in the magazine. Each month we receive a few copies of the papers in the issue, which we are happy to send out—free of charge—upon request. This supply of tearsheets (as long as copies last) is kept on hand for about two years. Save those coupons for ordering SME Preprints only.—*Rixford A. Beals*



JOSEPH L. GILLSON

AIME PRESIDENT 1960

As President-Elect of AIME this past year, Dr. Joseph L. Gillson has been doing not one but three jobs for his profession and the Institute besides his full-time position as chief geologist of du Pont. First, as an active board member and traveling emissary of the Institute. Second, as Chairman of the Member Gifts Committee of AIME for the new United Engineering Center. And, last but not least, as editor-in-chief of the new third edition of *Industrial Minerals and Rocks*. His chores on this authoritative volume alone were enough to keep most men busy, since he worked personally with every step from manuscript to page proof.

Introducing Dr. Gillson as AIME's President for 1960 is almost superfluous—for, as one of the most travelled men to ever hold this office, he is on a first-name basis with a tremendous percentage of the members, not only of AIME, but of other groups in the mineral industry.

No newcomer to professional office he has been vice president of the Mineralogical Soc. of America, president of the Soc. of Economic Geologists, and president of the American Geological Inst. He is also a fellow of the Geological Soc. of America. His doctorate in science is not honorary (Massachusetts Institute of Technology, 1923) but honors began with his college days at Northwestern where he graduated magna cum laude. He was also Sigma Xi and Phi Beta Kappa.

After service with U. S. Navy during World War I, he completed his education. Following early years of teaching at Harvard and MIT and field work with the USGS, he joined the du Pont Co. in 1929 and served with them until the present. As geologist and later chief geologist, his travels for du Pont took him across most of the world in search for a long list of raw materials including sulfur, titanium, fluorspar, manganese, and others. In 1940 he served as special geological adviser to the government of Travancore, India.

More recently he has been honored by AIME itself. As the 1957 Jackling Lecturer his topic was *A Geologist Looks at Industrial Minerals* and the citation on the accompanying award read for "his significant contribution to the advancement of economic geology, his leadership, and his keen sense of professional responsibility."

Besides representing the Institute in many ways, he has been particularly active in the Industrial Minerals Division of which he was Chairman in 1947. Since then he has been an AIME Vice President and Director for the periods of 1951-1953 and 1956-1959.

In other professional activities his habits of intense work have resulted in publication of more than 30 papers and of several patents. A number of his papers appeared in *AIME Transactions*. In recent years he has been widely known for his work and publications on titanium occurrences across the world, in placer and nonplacer deposits.

It suffices to say that despite degrees, awards, honors, and the highest offices his professional colleagues could offer him, Dr. Gillson has retained a completely unpretentious outlook.

A member of the staff who wanted to introduce him at a reception recently discovered after four tries with "Dr. Gillson" that he caught his attention quicker if he murmured "Joe."

In electing a President for 1960 AIME not only found a man who has already proven he can do three jobs at once, but the Institute also gained a first lady who has traveled almost as much as her husband. Dr. and Mrs. Gillson were married in 1918, and have three children and four grandchildren. As Dr. Gillson's constant companion Grace is already well known throughout AIME, and it is not completely said in jest that she keeps her suitcase packed and on rollers!—*R. A. B.*

YOU'LL NEVER BURN OUT AN AIR TOOL

with the new Le Roi LO-380 line oiler...

EMPTY OILER SHUTS OFF AIR!

Here's how the LO-380 Saves Tools—Cuts Repairs!

(1) Inlet reed valve meters air into the oil-resistant bellows

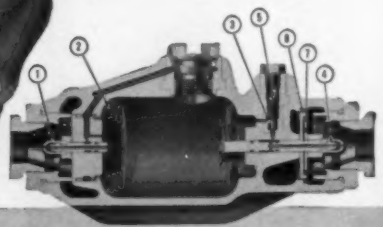
(2) which creates pressure that forces regulated amount of oil through porting connected to the needle valve (3) and the porting connecting it to the outlet reed valve

(4) through which oil is injected into the air stream.

(5) Set screw permits easy external adjustment of oil feed during operation.

(6) Positive pressure differential valve assures correct oil feed for all air flows — eliminates oil waste.

(7) Shut-off valve automatically stops air when oiler is empty. As oil supply goes down, bellows (2) expand and contact the shut-off plunger, depressing it until the valve reaches the automatic shut-off position.



That's right! *You'll never burn out an air tool with the new Le Roi LO-380 on the job!* When the oiler runs dry, it automatically shuts off the air! The "no oil — no air" design prevents unnecessary wear on critical parts — cuts repair bills — extends tool life!

The new line oiler assures positive lubrication for air tools — delivers a steady mist of oil at 10 to 150 psi — and keeps it flowing until you shut the air off, or until the empty oiler shuts it off automatically. Metered oil flow provides exceptional economy, prevents oil splurges. As a matter of fact, the LO-380 will pay for itself in a short time through oil savings alone!

Oiler permits easy external adjustment of oil feed — provides full one-pint capacity. Lightweight—only 9 lbs.—it's easy to use, easy to move—operates in any position. Oiler can be refilled under pressure while air tool is in operation.

Contact your nearest Le Roi distributor for details — or write to Le Roi Division, Westinghouse Air Brake Co., Milwaukee 1, Wisconsin.

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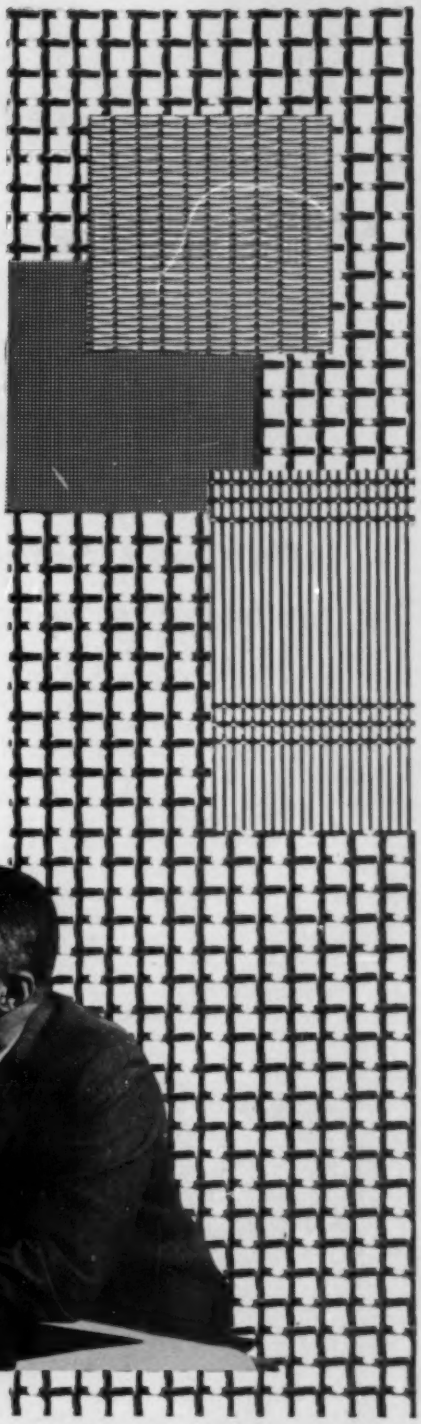

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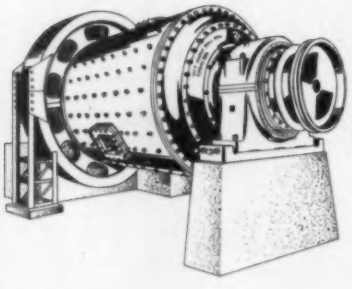
Let's grind down inflation in 1960!

Mine and Smelter offers you its cooperation, with these cost-cutting services . . .

▶ **engineering consultation on grinding problems** ...here you'll have the advantage of Mine and Smelter's imagination to originate, and experience to produce, ideas and equipment for lower cost grinding...with a proven record of innovations such as the low pulp line principle of grinding, large diameter mills, 2-stage grinding.

▶ **equipment consultation**...here you'll have the advantage of Mine and Smelter's 45 years' specialized experience in custom engineering its Marcy Mills to each particular problem...a service which has proven to give lower-cost-per-ton grinding.



▶ **a "Blue-Chip" long term investment**...here you gain dividends from Marcy's dependable 24-hour-per-day operation, year after year, with low operating and maintenance costs. And, there are no Marcy Mill orphans...you are always assured of getting the correct, and fairly priced, replacement parts; plus continuous cooperation from "the company that cares enough to give you the best."

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ANNUAL REVIEW
MINERALS BENEFICIATION

INTRODUCTION —H. R. SPEDDEN

Each year at this time we take stock of our annual technical accomplishments in an effort to highlight our successes and spur our industry on to greater heights. As we roll on into that period which is generally billed as "the fabulous sixties" we should take a more far-reaching look at our technology.

Just ten years ago one annual review stated "Domestic reserves of high-grade iron ores in the Lake Superior districts were reduced excessively during the war years, and greater attention is now being given to the eventual use of the taconites containing about 30 per cent iron. . . . The large steel companies, however, are more interested in acquiring and developing high-grade deposits in Labrador, Venezuela, Chile, and Liberia than in the Lake Superior taconites." These predictions were perhaps true, however, the technological effort placed on the taconite problem with sums of money comparable to major public works is now a part of our recent history and the "eventual" has come into being.

At the same time, we have become familiar with terms such as IX, SX, RIP, LPF and R-N, all of which were not mentioned in our reviews of ten years ago, even though the development of these processes was well under way. These are just some of the successful examples of the greatly expanded effort during the past decade to blend the principles of mineral dressing, pyrometallurgy and chemical engineering into new processes for the more economical extraction of the mineral values from ores. This amalgamation of technologies will continue as advances are made in each specific scientific area.

In his February, 1959, analysis of the trends of mineral commodity prices, C. W. Merrill stated "It seems strange, then, that rapidly rising demand met from irreplaceable reserves should be accompanied by a downtrend in prices when measured in terms of average wages or even in deflated dollars. What factors have made this anomaly possible? There are many but advancing technology and discovery are by far the most important."

An example of the effects of our advancing technology may be found in the annual reports of one of the large copper companies. In 1938 that company was treating ores containing 1.10 pct Cu, ten years ago the figure was 0.95 pct Cu and last year the average had dropped still further to 0.85 pct Cu. It is true that the price of copper has increased substantially but so has the general price index and thus the price of copper relative to the costs of producing it remains reasonably constant. The fact that lower and lower grades of ore may be profitably treated then must, by and large, be attributed to gradual improvements in the technologies from mining to final use. The same analysis holds to a greater or lesser degree for most mineral products.

This irrevocable advance of process technology is usually overlooked in our enthusiasm for publicizing newly discovered and exciting developments. Both facets are important. One represents the creative and combined efforts of most of our professional colleagues, and the other, the output of our star performers. The results may again be shown by example. The current price of copper per pound is essentially the same as the price of cotton, yet copper is produced from an irreplaceable source, it is mined and processed in plants requiring very large capital investments to make possible the extraction of but 17 lb of metal from a ton of rock and the final product is usually not destroyed in use. The fact that a metal can be produced under these conditions, at a comparable price to an agricultural commodity which requires rather simple processing and has a short life, is certainly a testimonial to the technological skills of our profession. This analysis also leads to the conclusion that our economy will be able to absorb the higher metal prices which will be required to treat today's submarginal mineral deposits and thus to ensure a continuing and expanding supply of needed metals.

We urge, therefore, that you read the details of our current accomplishments and realize that these are but parts of a pattern guaranteeing both greater availability of our common mineral products and the economic production of many of the newer metals which will be needed in the future. Look back ten years at uranium, titanium, zirconium and hafnium and then look ahead to columbium, rhenium, the rare earths, scandium and others, to realize the part we must play in our growing culture. The future does indeed look bright for the mineral processing industry.

MILL DESIGN

A. A. WALLACH—H. J. KAISER CO. (CANADA) LTD.

The year 1959 has not shown any startling changes in mill design but has rather been the time of consolidation of gains made over the past few years.

"Be not the first by whome the new is tried
Nor yet the last to lay the old aside"

is nowhere proved with more finalty than in the design and construction of ore concentrating and reduction plants.

Over the years, it has become evident that designers and operators are reluctant to install radical innovations in a new plant until they have been proven in an existing operating plant.

At the present time, x-ray spectrometers are being tested for continuous assay of mill products, automatic grinding controls tied into density, measurements of classifying devices are being tested in certain Southwestern plants, and these and other innovations of their type will, upon proof of their worthiness, become tools of the designers in the near future.

The trend to larger units in grinding, pumping, flotation, and crushing is continuing and it is felt that the optimum power consumptions have still not been reached.

The use of autogenous grinding systems in Canadian iron ore plants and pilot plants, indicates the advantages which may be gained by these systems when used in the proper place.

A factor of major significance is the increasing trend towards the adaptation of chemical plant techniques in concentrating plant mill design. The impact of the uranium industry has been one of the major factors in this trend.

The resurgence of gravity concentration during the past year has indicated once again the fact that no one process is a cure-all for all industry ills. This resurgence has brought into focus again the twilight zone of classification between screening and classifiers and the next few years should see considerable development work done to solve the problems which have been raised.

Solvent extraction operator checks a solution flow meter in the stripping circuit of the Kermac Nuclear Fuels Corp. mill near Grants, N. M., nation's largest uranium production unit with a rated capacity of 3630 tpd.

The success of various types of roasters and direct reduction units in the iron ore field (as yet more or less in pilot plant stages), has resulted in the mill and concentrator design field.

CRUSHING AND GRINDING REVIEW

C. L. SOLLENBERGER—ALLIS-CHALMERS MFG. CO.

Trends in the field of crushing and grinding are toward bigness and toward automation. Bigness in equipment design is apparently a natural development of the bigness of ore processing plants designed and built in recent years.

EQUIPMENT DEVELOPMENTS

As an example, jaw crushers are becoming larger. The world's largest jaw crusher is now operating in a French stone quarry. It has an effective opening of 8 ft 3 in. x 5 ft 3 in. and can be fed with 10-ton blocks of stone and by shovels of up to 6 cu yd capacity. Its output is 600 to 800 tph with a 12-in. setting on run-of-quarry rock. Made by Appareils Dragon S.A. of France, it is of a Blake double-toggle standard type.

The gyratory crusher is entering several new fields. Because of its high capacity a 42 x 65-in. model is used as a primary crusher in a recent application in the cement industry. Another new market for the gyratory crusher may be in the production of ⅛ in. to 100 mesh sinter sand for self-fluxing sinter wherein fine limestone is added to the sinter bed. The crushers themselves have been improved. The features formerly available on only the largest models are now available on smaller size units, such as the Allis-Chalmers 736 Hydrocone. This crusher is well accepted by aggregate producers and has been successfully used in portable rubber-tire mounted plants. The Hydroset control allows extremely rapid adjustment of the setting. A system for automatic adjustment and control of the crusher setting is now in the development stage. Many crushers already in use are being converted to hydraulic adjustment systems. Other companies, such as Nordberg, are beginning to offer similar systems.

During the year several new lines of twin roll and impact type crushers have been announced. Some of these have hydraulic adjustments which enable quicker changes of setting to meet changes in requirements. A roll crusher and a hammer mill are said to have been combined in the rollhammer. The combined crusher principle is said to reduce overall power consumption although the roll and the hammer are independently driven at different speeds. Manufactured by O'Brien Industrial Equipment Co., it is adapted for crushing down to 6 mesh in closed circuit. In the Joy-Hazemag impact crusher (of West German origin) the rotor throws the feed against impact plates suspended within the crusher. Adjustment of impact plates and rotor speed, both possible during operation, control the product size.

The abrasive wear problem of impact crushers has been attacked in the D-Centegrator crusher. Made by Simplicity Engineering Co., the crusher has a rotating cage and outer shell which catches some of the raw material and forms it into a hard packed cake. Impact is against this coating and not against the steel itself. Another approach to the abrasives problem is the increased use of tungsten carbide parts. The variety of tungsten carbide type materials now available should caution the user to select the one most appropriate for each particular application.

Fluid energy mills are also experiencing the trend toward bigness. A 42-in. diam Micronizer mill recently constructed has 50 pct greater capacity than the older 36-in. mill.

Rod mill designs are also getting bigger. The largest such mills are the pair of 12 x 16 ft Marcy mills at Duvall Sulphur & Potash Co.'s new copper mill at Tucson. The trend to larger mill designs is getting far ahead of the design of auxiliary apparatus such as classifiers and flotation cells. Because of this limitation two smaller mills are sometimes preferred for flexibility in circuits although a larger mill would be preferred if the mill were to be judged on its merits alone. There is a trend toward the use of rod mills in cement plants, both in raw material circuits and in the clinker circuit. Another potential field is in the grinding of coal in which industry it is reported that a ball-peb mill has recently been converted into a rod mill.

Ball mills particularly reveal the trend toward bigness. The largest mills built today are for the cement industry and are in the 12 x 36-ft size range. They are driven by 2500 hp motors. A 14 x 21 ft ball mill is now in the design stage. A variation in drive mechanism has been used on at least one of these large mills in that the peripheral ring gear drive long common to ball mills has been replaced by a central drive at a trunnion. This large mill diameter has brought attention to a hitherto unrecognized factor in ball mill design, the "slump" factor. This factor, which is especially pronounced in wet, overflow ball mills may impose a practical limit to mill diameter in that it becomes important at mill diameter to ball diameter ratios greater than 80 to 1. This factor prevents the mill from drawing as much power as would be expected. One such mill draws 12 percent less power than had been predicted. A possible solution may be a boost in operating speeds, but this possibility has not yet been investigated. The trend toward larger mill sizes is also continuing in the mining industry. Two 13 x 12 ft overflow ball mills at Climax Molybdenum are still the

largest after having been in operation several years. Close runners-up are the two 12½ x 14 ft ball mills at Duvall Sulphur & Potash Co.

Another trend noted is the increasing popularity of the double wave liners in ball mills. Also, it has been found that dry ball mills may be advantageously operated at speeds slightly greater than the 77 pct of critical speed which is considered to be the optimum speed for wet ball mills. Grinding in mills at super-critical speeds has also received further attention since publicized by R. Hukki a couple of years ago. H. E. Rose reports that the charge within such a mill oscillates within the mill shell in a pendulum-like manner, thus giving rise to heavy blows.

The vibrating ball mill, which was commercially introduced a year ago after many years of development, is now in use in over 20 diverse industries, and is also available as a pre-engineered dry grinding plant. This 15 x 15 in., 15 hp mill made by Allis-Chalmers requires no foundation, and has a large capacity for its size. A larger 30 x 30 in, 75 hp model was introduced Dec. 1, 1959.

Professor A. W. Fahrenwald has recently published some additional information on his somewhat similar device, the gyratory ball mill. This mill differs from the vibrating ball mill in that is gyrates about a vertical axis, has a large amplitude of vibration, and has a rather slow speed of operation.

AUTOGENOUS GRINDING

Several recent papers by H. Hardinge, B. S. Crocker, and by others have discussed recent trends in the field of Autogenous Grinding. Three main types of mill are now current. The dry coarse crushing mill where the product is removed by an air sweep is typified by the Aerofall mill which can handle feed up to 12 in. It is suitable for crushing soft materials down to the natural grain size. A mill effective down to the same size range but without an air sweep is known as the Hardinge Cascade Mill. This mill with a peripheral discharge can be operated dry. It can also be operated wet with a grate discharge. A mill which is adapted for wet fine grinding and is not limited by the natural grain size has been described by B. S. Crocker. It is reported that other manufacturers in addition to the foregoing are interested in entering the field of autogenous grinding.

It is now generally accepted that for fine grinding autogenous mills, 1) the mill capacity is proportional to the specific gravity of the grinding medium, 2) the grinding medium should have the same weight, not the same volume, as the optimum size of steel ball replaced, 3) pebble mills should have a low level grate discharge; overflow mills have not been successful, 4) methods of control can be sufficiently rapid so that these mills can be readily incorporated into automated mill circuits.

OPERATION AND CONTROL

The trend in plant design is toward the increased use of automation. The Duvall Sulphur & Potash plant which started operating in February 1959 is noted for its high degree of automation. Trailer mounted, portable crushing plants are obtaining increased versatility through automation. Downtime in crushing and grinding plants has been decreased by the introduction of a device for stopping a mill in a position which allows easy access to manholes. Other operating improvements include the use of a retractible working platform below gyratory crushers, the increased use of Ni-Hard crusher concaves instead of manganese steel concaves for longer wearing life, and the use of submerged-arc hard-surfacing in the rebuilding of wear surfaces on roller mills. An improvement in mill control was made by Hardinge Co. by adding recording features to the Electric Ear Control system.

RESEARCH INTO NEW METHODS

Unconventional methods of comminution are being investigated by several research organizations. During the past year the use of high-frequency electromagnetic induction was patented as a method of fracturing taconite. Fracturing apparently results from tensile failure due to localized differential thermal expansion in the magnetite-bearing quartzite rock. A Soviet publication also mentions similar experiments in Russia.

Another Soviet innovation is the use of high voltage (up to 120 kv) electrical discharges under water which causes crushing of rock within the vicinity of the discharge. An application of this "Electro-hydraulic effect" is in the preparation of material for optical glass where no iron contamination is permissible. The device as yet is of low capacity.

Studies have been made on the economics of crushing with nuclear detonations, which effectively break rock with very little contamination. Calculations by the Colorado School of Mines Research Foundation show that nuclear blasts and in-place leaching may be the only way to make a profit from 0.50 pct copper ore body. Another study at Georgia Tech is attempting to create fine particles by radiation crushing of kaolin.

PUBLICATIONS

A notable bibliography of comminution literature was published this past year, *Crushing and Grinding, A Bibliography*, by the Department of Scientific and Industrial Research (Great Britain). This book contains a series of short reviews as well as a classified bibliography with over 2800 entries. A book by H. E. Rose and R. M. E. Sullivan entitled, *Ball, Tube, and Rod Mills*, thoroughly treats, by means of dimensional analysis, the effects of the various parameters governing the operation of these mills. The proceedings of an April 1958 conference in London have been recently published as *Mechanical Properties of Non-Metallic Brittle Materials* which deals with several theoretical aspects of comminution.

A pair of notable papers were presented at the September meeting of AIChE in St. Paul, Minn. by W. J. Kenny, "Slow Compression Crushing of Single Particles of Glass" and by R. H. Zeleny, "The Dissipation of Energy in Single Particle Crushing". These papers discussed work done in collaboration with Dr. E. L. Piret at the University of Minnesota. Surface areas of products and the amount of heat generated were respectively compared with the energy input for crushing. The Crushing and Grinding session at the 1960 AIME Annual Meeting will be a symposium in which most of the papers deal with this same subject, energy-size reduction relationships. The degree of interest and activity shown in this subject both here and abroad should lead eventually to a universally accepted comminution theory.

CONCENTRATION

O. F. TANGEL, R. J. BRISON, AND J. F. SHEA—BATTELLE MEMORIAL INSTITUTE

The resurgence of gravity concentration during the past year has indicated once again the fact that no one process is a cure-all for all industry ills.

A new twist in the old process of hand sorting of ores is reported by E. and G. E. Strandstrom. Termed "straight-line sorting", the system provides for alignment of pieces in straight lines rather than at random across a wide belt. Technical and economic advantages are claimed.

A new dry method of mineral separation has been developed by Battelle Memorial Institute for the International Salt Co. The process involves selective heating of one or more of the minerals and then separating the slightly heated particles on a belt coated with a heat-sensitive resin. In the case of rock salt, the diathermic property of the halite permits the use of radiant heat to heat the impurities while the relatively pure halite particles remain substantially unheated. A 35 tph unit, in operation at the company's Detroit mine since Mar. 1, 1957, shows an over-all cost of 33¢ per ton of cleaned salt. Application of the new method for separation of other materials is anticipated.

The Smith separator for separation of asbestos fiber from crushed rock consists of an inclined, perforated conveyor belt, operated at a fairly steep angle over drums at rather short centers. Rotating beaters cause fines to pass through the perforated belt or wire mesh screen while fibers are carried to the top. Power required is 3 hp for a 25 to to 30 tph plant.

Air tables are used to concentrate pyrrhotite at the Gossan Mines, Va. Although not new, this operation represents an interesting application of air tabling of sulfides in the −3 + 48 mesh range. From a typical feed analyzing 25 pct S, a concentrate of 33.7 pct S and a tailing of 8 pct S are produced. Each table treats from 4 to 8 tph of ore depending on feed size.

Pilot-plant results on dry concentration of magnetic iron ore have been reported by Cavanagh. By the use of dry concentration a possibility of saving as much as 20 pct of the over-all processing cost is indicated.

At the Mine Prince Leopold Concentrator, Kipushi, Belgian Congo, renierite is recovered from copper flotation concentrates with ferrofilters to obtain germanium concentrates assaying from 0.3 to 1.5 pct Ge with recoveries between 10 and 30 pct.

The application of cyclone heavy-media separation for coal cleaning in European washeries was discussed by Dr. Krijgsman of the Netherlands. Sixteen cyclone washing plants are in operation, ranging from 20 to 200 tph of feed with particle sizes from 0.5 to 19 mm. Magnetite losses range from 0.3 to 0.5 kg per ton of feed. Medium density can be kept constant within a range of 0.003. Cyclone diameters are generally 20 in. Results obtainable on typical U. S. coals are predicted.

The gravity concentrator at Steep Rock Iron Mines was described by Huston. The ore is essentially goethite. The ore is scrubbed and screened to provide a + ¼-in. feed to the heavy-media drum. The − ¼-in. material is separated in a wash classifier to produce a sand feed for the Remer jigs. The classifier overflow is deslimed at 200 mesh to produce a + 200-mesh feed to spirals. Work is in progress to recover iron from the − 200-mesh size fraction.

Concentration and final recovery of diamonds at the Williamson Diamond Mine were described by du Toit. Heavy-media cones with ferro-silicon treat the −1.5 in. + mesh feed. Sink fraction is 0.4 pct by weight of con feed, and diamond recovery is about 96.6 pct. Cyclones with magnetite treat −10 + 16 mesh. Sink fraction is 0.5 pct by weight of cyclone feed, and diamond recovery is about 99 pct. Sink fractions are given an attrition grind. Plus 7 mesh sized fractions are conditioned with whale acid oil and caustic soda before treatment on grease belts where recovery is about 99 pct. Minus 7, + 16 mesh is differentially ground, dried and concentrated by specifically designed electrostatic separators which recover about 99 pct of the diamonds. Final concentration is by hand sorting.

Fiber-glass spirals, with zircon sand added to the surface to improve wearing qualities, are being used in Australia by rutile and zircon producers.

The Russians report laboratory work on electrostatic separation of zircon and apatite after HF treatment. HF treatment, in 5 to 10 pct solution, results in the formation of a thin layer of CaF_2 on apatite. The layer has a finely crystalline structure with high absorption power for moisture, which increases the conductivity. With essentially pure minerals, the zircon concentrate contained 95 pct zircon at a 91.5 pct recovery, and the apatite concentrate 90 pct apatite at a 95 pct recovery.

Concentration is playing a minor but increasing role in uranium ore processing. At least four U. S. uranium mills use some form of physical concentration as part of their operations.

The new by-product plant at Climax was described by Burk. Treating 32,000 tpd, with approximately 0.03 per cent WO_3, trace Sn and 1.25 pct pyrite, the plant preconcentrates the tungsten, pyrite, and tin with spirals and cyclones. Cyclone underflow with 30 pct pyrite is treated by flotation to produce a concentrate of 50 pct sulfur. Flotation tailings are sent to slime tables to produce a concentrate which is then treated in another flotation circuit to remove monazite containing phosphorous. The froth product containing the monazite is a low-grade tungsten concentrate. The flotation tailings, after dewatering and magnetic removal of metallic iron, are dried and then screened to discard the +40-mesh fraction. The

screen undersize is separated magnetically to produce 72 pct WO_3 and 40 to 50 pct WO_3 concentrates. Magnetic rejects are screened at 50 mesh and a 40 pct tin concentrate is produced by tabling the undersize.

Flotation of sized feed is practiced at Cyanamid's Grange Park phosphate rock plant. Hydraulic classification produces +20 mesh, −20 + 60 mesh, and −65 mesh fractions. The + 20 mesh is screened to remove undersize. The −20 + 65 mesh fraction is deslimed, conditioned, and floated in pneumatic cells. The rougher concentrate combined with the −65 mesh is conditioned and floated. The second rougher concentrate is acidified to remove collector coatings and cleaned by cationic flotation of silica.

International Minerals & Chemical has revised its Carlsbad potash flowsheet to pretreat the coarse and fine particles in separate circuits before flotation of the combined feed. The ore after grinding, screening, and pulping is classified into a coarse and a fine fraction. Clay is removed in both circuits, the coarse is conditioned with a petroleum oil and amine, the fine with starch to inactivate clay. After conditioning, the two streams are joined before conventional flotation. IMC claims K_2O content has been raised 0.6 pct, starch cost reduced 46 pct, amine cost reduced 10 pct, and efficiency increased 3.6 pct.

Klassen and Yagodkina (USSR) studied the problem of removal of pyrite and marcasite from coal by flotation. Differences were found between the flotation properties of iron sulfides of coal origin and of ore origin. The iron sulfides from coal absorb more xanthate but the absorbed xanthate is relatively ineffective. Differences in calcium absorption were also noted. The peculiar behavior of coal pyrite and marcasite is attributed to the presence of organic materials at the time of their formation.

Interest and activity in fine bituminous coal flotation appears to be increasing, with a number of new installations completed or in progress. Chang and Dasher described improvements made at the Crucible coal mine in Pennsylvania by adoption of flotation and other changes. The filter cake ash was reduced from 18.40 pct to 8.17 pct.

Beneficiation studies on Arkansas manganiferous limestone by the U.S. Bureau of Mines have been reported by Fine. From feed materials containing less than 5.0 pct Mn, ferrograde concentrate analyzing 41.7 to 49.5 pct Mn was obtained with recoveries of 48 to 66 pct. A combination of tabling, flotation, and leaching was used. Fine states that in view of the results, these deposits are considered a potential source of metallurgical manganese. Ores in which braunite and/or hausmannite are the principal manganese minerals are most suitable for concentration.

Interest in pyrochlore concentration continued with further indications of the major progress made in the past few years. Columbium Mining Products (Coulee-Headway) reported continued improvement in results by a method in which the key step is flotation with a combination of long-chain amines, diamines and wetting agents. Kennecott Copper Corp. obtained British and U. S. Patents on flotation of pyrochlore and other columbium-bearing minerals employing 8-quinolinol as a collector. Cominco has also developed a flotation procedure for the pyrochlore from Beaucage Mines. Indications are that it is now practical to produce a concentrate of at least 20 pct Cb_2O_5 from ores containing only 0.3 pct Cb_2O_5. Although some problems remain, such as cost of reagents, the rapid progress in this field is an interesting illustration of what can be accomplished by intensive experimental work on flotation.

Details of the LPF process at Kennecott's concentrator at Hayden, Ariz., were published. The addition of LPF has resulted in the recovery of 2 lb of nonsulphide copper per ton of ore, and has increased the overall copper recovery by 10 pct. Both the sulfuric acid and the sponge iron used for LPF are produced at the plant.

The results of experimental work on flotation of chrysocolla were reported by Jaekel. The chrysocolla was activated by sulphidization and floated with a combination of Aerofloat 31 and American Cyanamid Reagents 404 or 425.

Differential flotation of copper minerals (mainly chalcopyrite) and cobalt minerals (Co_3S_4 and cobaltiferous pyrite) at Chibulma Mines, Northern Rhodesia, has been described by J. E. Harper. Lime (pH 11) and cyanide are used to depress cobalt minerals during copper flotation. The cobalt minerals are then recovered after activation with copper sulfate at pH 9.

D. W. Frommer and M. M. Fine of the U. S. Bureau of Mines reported (RI 5444) on experiments in concentrating lead sulfide slime. Starting material was mill tailings (about 70 pct finer than 400 mesh) assaying 0.20 pct Pb. By using larger than normal amounts of xanthates and sodium sulfide, a recovery of up to 45 pct in a rougher concentrate analyzing up to 6.5 pct was indicated. The problem of upgrading this concentrate was to be considered later.

The use of sodium sulfide was also considered by S. L. Rokhlin (USSR) in a study of flotation of finely disseminated oxidized lead ores. Among other factors, the effect of aeration on the stability of the sulfide film was studied. A multi-stage process involving successively finer grinding and reflotation of tailings was recommended. Final grind is to 85 to 90 pct − 325 mesh.

Another USSR investigator I. N. Dukhanin, reported on a study of various frothers in selective lead-zinc flotation. Best results were obtained with technical cresol; the worst with terpene frothers and industrial phenol wastes.

Soviet work reported by I. Plaskin confirmed that the concentration of oxygen in solution plays an important role not only in sulfide flotation but also in nonsulfide flotation. S. V. Bessenov and others reported that the intensity of oxidation can be controlled by the pulp alkalinity; the higher the alkalinity, the more intensive the oxidation at a given oxygen concentration.

H. Neu (Germany) reported work which indicated that some collectors are more suitable for use with sodium sulfide than others. The lower xanthates, for instance, are stated to be more sensitive to a slight excess of sulfide than the higher xanthates. He concludes that, on ores which require sulfidization, collectors should be selected which are least sensitive to sodium sulfide.

I. Tomov (Japan) reported experimental work which supported the view that, in many cases, mixtures of collectors are more effective than single collectors. Advantages indicated were lower reagent consumption, faster flotation, and higher concentrate grades.

SOLIDS-LIQUID SEPARATION W. T. MARSTON—DORR-OLIVER INC.

Both very large and very small countercurrent decantation plants started up in 1959. Kermac Nuclear Fuels has two parallel lines of six acid proof thickeners, each 120 ft diam of rubber covered and stainless steel construction in tile lined prestressed concrete tanks. The Cuban American Nickel Co. plant started up late in the year and has a very large countercurrent decantation system to wash nickel free from their leach residues.

A midwest hydrometallurgical firm flowsheet uses five CCD stages, each a 10 ft diam machine, certainly the smallest commercial CCD system this year.

Countercurrent filtration flowsheets were not as widely used as in the last few years of carbonate leach uranium mills.

Water recovery from tailings is an economic necessity for every new plant as shown by the installations at Central Farmer's Fertilizer, San Francisco Chemical, Duval Sulphur & Potash, etc. Even the older plants, located and built in a day when water was plentiful, are now feeling this necessity. The first tailings thickeners for Kennecott at Hayden, Ariz. and for Anaconda in Montana are in planning or construction.

INSTRUMENTATION

The trend towards automation of mineral beneficiation plants increased in strength during 1959. While the goal is automation, as exemplified by the modern oil refinery, it must be admitted that the minerals beneficiation industry is only at the stage of instrument control of some unit operations.

The modern oil refinery and many modern chemical plants are striking examples of automated control of complicated processes. The nerve center is usually an instrument-laden console arranged for a diagramatic flowsheet presentation of instrument readings and exhibiting automatic operation. Throughout rates, monitoring the presentation, and acting on danger signals are the function of the operator. This provides very low labor costs in relation to product value and a very uniform product.

There are two major reasons why mineral beneficiation hasn't embraced this concept. One is the varying nature of the feed and the second is the lack of instantaneous measurement of basic controls such as particle size and mineral content. As N. Arbiter pointed out last year, the two reasons are not interrelated.

A uniform feed to a minerals beneficiation plant is attainable (although not necessarily practical). Once attained, an automated mill is practical since we can now measure, control and intercontrol all functions short of size control and mineral content. With uniform feed, particle size and mineral content of various streams would be adjusted to best value during the startup period and thereafter left alone. This does not solve the more immediate and much more common problem of non-uniform feed. As soon as variations in mineralogy and grindability are involved, the problem is still to provide instantaneous, or at least very quick, measurement of particle size and mineral content. Particle size measurement should be universal when it is solved—mineral assay will be more diverse.

The 1960 AIME Annual Meeting will provide more than usual attention to instrumentation. The Homestake—Sapin uranium mine in New Mexico has probably the most extensive use of instruments to date. Duval Sulphur and Potash's new copper concentration in Arizona is a close second.

Hydrometallurgical flowsheets generally can adapt instrumentation more easily and with immediate benefits from known techniques since they can often fulfill the uniform feed requirements, but progress in this field is not as rapid as could be expected.

EQUIPMENT DEVELOPMENT

Air lift agitation for disk filters is in successful operation at Duval's new Esperanza mill. The cake is uniform and smooth; capacities are higher and cake moistures lower than expected. This is not a new development since several Canadian basemetal producers have been using air lift agitation for some years and air lift agitation has been used on drum filters as long as thirty years ago. For the coal industry fine refuse filters shows a definite tendency towards individual pans for each section of a disc filter and no agitation—proving once again there is no universal pattern for every filtration problem.

One of the operating problems of any continuous filter is progressive blinding of cloth media. This can be caused by chemical precipitation in the cloth, by wedging of particles into the cloth, by oil borne in the blow-air, etc. Sooner or later, the unit capacity of the filter drops to where the filter must be shut down for media cleaning and restoration of capacity. This means that the design capacity of any filter using cloth media must be a compromise. If the cloth media could be removed from the drum on each revolution and cleaned, this would be alleviated. Potash Co. of America (U.S. Borax & Chemical Co.) did so some years ago and have operated their slime filters in this manner ever since. Two commercial versions of this type of filter have been developed and are meeting with success.

Where corrosion resistance is necessary, stainless steel and rubber covering were the usual and expensive choices. Small diameter drum filters are now available constructed of plastic reinforced fiberglass. Should strength, abrasion and corrosion characteristics remain as satisfactory as first indications show, there is certainly no reason why this material shouldn't be extended to larger machines and to increased component usages for savings.

One more trend, or the possible appearance of a trend, is worth mentioning. For many years gravity was the major force whose effect was harnessed to provide liquid-solid or solid-solid separations. The use of hydraulic cyclones simply magnified the force of gravity many fold so far as classification was concerned and provided the spectacle of a small hydraulic cyclone, replacing large classifiers. The first signs of a similar displacement of thickeners and filters is discernible although it may be wishful thinking. Two industrial minerals at least are being washed and delivered at a low moisture final product by centrifugal machines. In both cases, the particle size analysis lends itself to such treatment. Nevertheless, this could be a chink in the armor.

RON ORE BENEFICIATION

The year of 1958 was one of lowered iron ore production and and during 1959 production was interrputed by the steel strike. As a result of this the progress of iron ore beneficiation was somewhat slowed, at least in regard to reduction of ideas to practice.

On the other hand there appears to have been a rather unusually large number of ideas that are being discussed, tested or tried on a pilot plant scale.

It appears that one of the largest potential reserves of concentrating-type iron ore occurs in the so-called Wabush area of Labrador. In this cold climate there is considerable incentive to develop dry methods of concentration. This has been accelerated by the successful application of dry methods of grinding to this type of specular hematite ore.

The Aerofall mill has been extensively tested on this material. The newer Hardinge Cascade mill which can be operated either wet or dry is also being tested on these ores.

For dry concentration, the dry high intensity magnetic separator using an induced roll is receiving attention. This machine can be adjusted to separate hematite and limonite by magnetic means. It appears to work well on materials that are reasonably free of middling particles and that are not too finely disseminated. Also receiving attention are the high tension or electrostatic processes such as the Carpco machine and the Dings Coronatron.

Dry concentration of magnetite ores is also being vigorously developed, particularly in Scandinavia. An advantage of these machines is that magnetic forces and centrifugal forces can be easily combined. Representative machines are the Mortsell where stationary magnets are located inside a rotating drum, the Laurilla where both the magnets and the drum shell rotate, and the Research-Cottrell where both the elements rotate but the drum is eccentric to the magnet assembly in order to aid removal of the magnetite.

In some work the Cascade mill is operated as a wet autogenous grinding device and it is then followed by spirals. A recent development which is gaining in popularity is the use of the Pocket Sizer in conjunction with cleaner spirals. This is a small single hydraulic sizer that attaches ahead of each spiral in place of the standard feed box.

On the Mesabi range in the older washing process the use of rotary scrubbers is gaining in popularity. A number of new installations have been made and it appears that the rotary scrubber has become a standard part of the washing flow scheme.

A number of new cyclone plants for — ¼ in. material are under construction or in the design stage. Fine mesh wash screens have been improved and developed in the last few years and the newer cyclone plants depend more on screen washing for media recovery. In this respect, the flow schemes now tend to be more similar to those of the standard heavy media process for coarse ore.

At one heavy media plant, a large Dorrclone was installed this season for the concentration of coarse ore. This extension of the cyclone process to coarse feed is said to have certain space and capital cost advantages.

Another interesting development has been the extensive testing of atomized spherical ferrosilicon, imported from Germany, in the heavy media concentrators of the Mesabi Range.

Flotation testing continues to receive much attention. A pilot plant is being operated on the Mesabi Range. In the special case of the Michigan specular ores however flotation has become commercially accepted at the Humboldt, Republic, and Groveland concentrators. The Groveland flow scheme is a combination of spirals and flotation while the other two plants depend on flotation only. Flotation of the slaty types of iron ores presents technical problems in many cases even in the laboratory. However, the development of high solids conditioning for relatively long time periods has greatly expanded the field of application of flotation.

The concentration of magnetic taconite has been expanded further with the start up of the Moose Mountain concentrator in Canada during 1959.

There has been considerable discussion of processes for concentration of the non-magnetic taconites. At the present time, the use of a reduction roasting process to convert the hematite and limonite to magnetite, followed by magnetic separation, appears to be most in favor.

In 1959 the Minnesota State Legislature established a new ore classification of semi-taconite. This is, broadly, anything between hard solid taconite and the material that can be treated in present commercial concentrators. Several semi-taconite pilot plants are presently in the discussion stage.

The use of direct reduction processes for iron ores continues to hold the imagination of the industry. Several new processes have been proposed and there has been intensive development of older processes. With all of the interest in this subject and with all the effort that is going into these processes it appears to be only a matter of time before we will see rather large tonnages of iron produced by some of the so-called direct reduction or sponge iron processes.

Annual Review — Minerals Beneficiation

PYROLYSIS AND AGGLOMERATION

M. E. VOLIN—HOUGHTON, MICH.

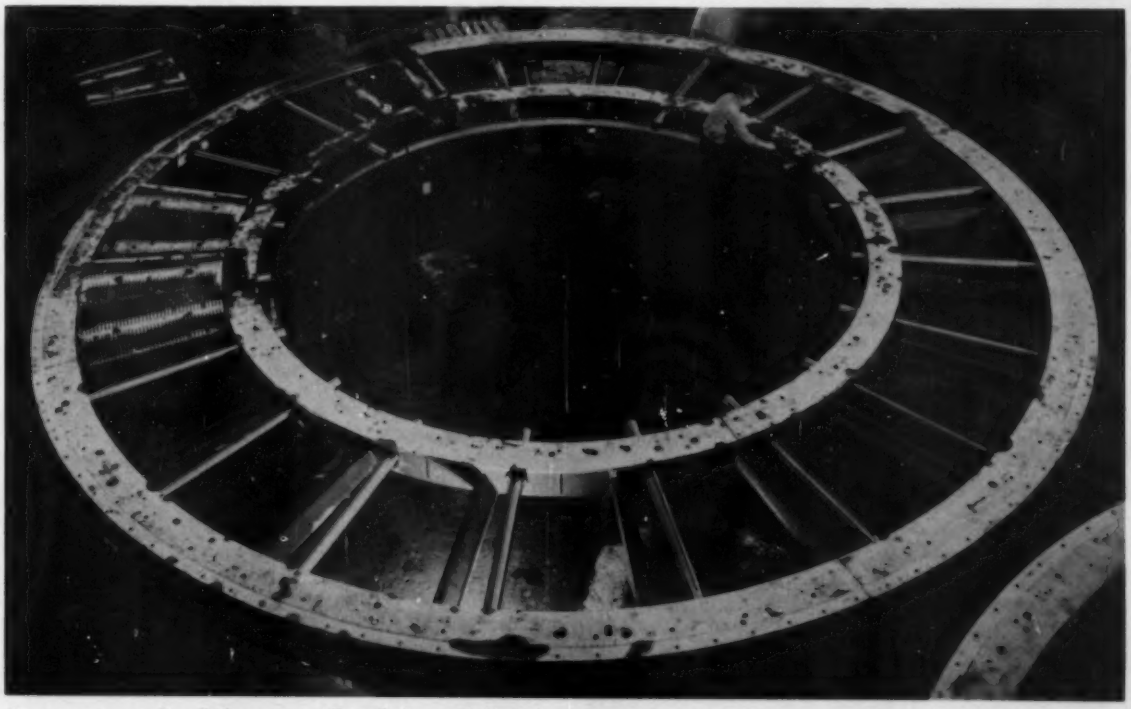
Variety is still the keynote in iron ore agglomeration—sintering, pelletizing, or nodulizing.

SINTERING

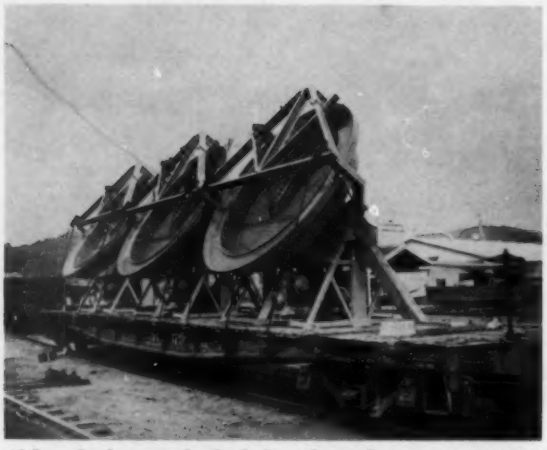
Sintering capacity has grown rapidly in the last ten years and upon completion of plants now in construction, U. S. sintering capacity for ferrous materials will reach a total of 64 million tons per year, enough to operate the nation's blast furnaces at full capacity on 50 pct sinter burden.

Four of the newest sintering plants are described in *Iron & Steel Engineer*, June 1959, under the title "Symposium on Sinter Plants." One of the sinter lines is 13 ft-2 in. wide, the largest in the world. Dravo Corp. has installed two new plants in this country under a licensing agreement with Lurgi of Germany. The straight line traveling grate machines feature induced draft coolers which lower the temperature of the sinter enough for it to be carried on rubber conveyor belts. Most of the new plants are designed to make self-fluxing sinter as well as regular sinter. The mix is balled in drums or discs before it is charged onto the hearth. Other features are automatic proportioning, improved mixing to achieve better aggregation of the particles making up the mix, radiant type firing, and electronic controls. At two Soviet plants, the sinter is charged hot (approximately 1,400°F.) into the blast furnaces.

The mechanisms of sintering are not fully known; they are complicated in that the product is a heterogeneous mass resulting from incomplete chemical reactions and it is effected by numerous factors including the physical properties of the charge constituents and the methods of handling them. However, much work has been done in recent years on sampling and testing sinters and studying the factors influencing sintering. The Soviets have engaged in a wide range of investigations of all phases of sintering, including the production of self-fluxing sinters. The mineralogy of sinters has been studied with the microscope and the x-ray. Recent investigations by the British Iron and Steel Research Association explain the relationships between air flow, heat transfer, and combustion. It was demonstrated that the fuel requirements are related to the heat requirements of the process while the air requirements are more dependent on the heat capacity of the sinter mix than on the oxygen requirement of the fuel. Investigations in this country of factors in



A crane-mounted radial press at Allis-Chalmers drills holes in one of two 25-ft diam annular coolers being furnished Humboldt Mining Co. The coolers will be used in conjunction with first full-scale operation of the Grate-Kiln system in an iron ore agglomeration process.



Although this article deals largely with iron ore activity other fields are progressing, also. This is not an antenna array for a new radar installation. Actually these three unusual-looking devices are mixing discs recently shipped by Dravo Corp., to St. Joseph Lead Co., Monaca, Pa. The 8-ft 6-in. diam discs will prepare a mixture of roasted zinc concentrates, fines, flue dust and coke breeze for agglomeration on the Monaca plant's sinter machines.

the mixing of charge materials have led to better aggregating methods that have increased the sintering capacity of existing machines. Under design is a data processing system for sintering plants which will gather and record data from various points, convert the data to engineering units, and print records. This system will be used in operational studies for the purpose of improving plant performance. The system can be expanded to provide direct computer control for optimum performance.

PELLETIZING

The ACL-grate-kiln (Allis-Chalmers adaptation of the Sepal Kiln), was selected by the Cleveland-Cliffs Iron Company for the new pelletizing plant under construction at the Humboldt mine and flotation mill in Michigan; this will be the first large-scale use of this equipment in the iron ore industry. The plant is scheduled to go into operation in June 1960 at the rate of 600,000 long tons of pellets a year. Cleveland-Cliffs researchers have been testing specularite flotation concentrates and other Marquette range iron raw materials in a four-ton per hour grate-kiln pilot plant recently installed at the Eagle Mills pelletizing plant. The objectives of the pilot mill operation are to train operators for the full scale plant, to monitor breaking-in operations, and to improve this process in its application to specularite concentrates.

Noteworthy improvements have been made in shaft furnaces used for pelletizing. Physically, the shaft furnace is about the simplest way to heat solids that can be made to flow downwards through a shaft. The countercurrent heat exchange between descending solids and the ascending gases (usually air) is efficient and provides high processing temperatures if the solids have ample heat transfer surfaces and are strong enough to maintain sufficient openings for the flow of the gases. Designs have progressed from a simple shaft in which all of the gases flow upward through the charge to modifications permitting partial by-passing of the gases. A recent design now in use in Minnesota and Quebec provides for about 60 percent of the required air to be admitted at the bottom of the shaft and the remainder to be admitted at the reaction zone; the latter portion is heated to the desired reaction temperature by direct combustion in the air stream. A further modification provides two separate chambers in the shaft, the lower one being an independent cooling chamber. Approximately 60 percent of the air is added at the bottom of the shaft to cool the pellets in the cooling chamber. The heated air goes through a heat exchanger where it heats incoming air for the reaction zone. The pellets leave the reaction chamber at about 1,000°F and are cooled in the cooling chamber to near ambient temperatures. With efficient heat exchange the air to the reaction zone is heated to nearly 1,000°F. This design greatly improves heat recovery and is said to reduce overall heat requirements to less than 750,000 BTU per long ton of pellets.

Much research is being done in the Soviet Union and some in this country on the factors influencing the physical quality of iron ore pellets. Particular attention is being given here to standardization of procedures by which the pellets can be tested in the laboratory and the results translated into improved plant operations. Measurements of the strength of coke at high temperatures reported by M. O. Holowaty and C. M. Squarcy at the 40th Conference of the National Open Hearth Steel Committee and the Blast Furnace, Coke Oven and Raw Materials Committee of AIME, 1957, indicated that the established tests of cold pellets do not adequately define their properties under blast furnace operating conditions and suggested the need for new criteria, methods and equipment. Other researchists have taken up this work and are conducting tests to define the properties of pellets under the atmospheric as well as the temperature conditions characteristic of the blast furnace. Work in Minnesota confirms earlier reports that coal admixed in the pellets is detrimental to the fired strength because it promotes formation of fayalite slag which influences discrete grain growth at the expense of stronger hematite bridging. Surface area measurements are under study as a tool for predicting pellet quality, as surface area has been shown to be related to green and fired strengths. Degradation of pellets in shipping and handling is due in part to cracks resulting from excessive loads on the green balls and internal stresses set up in firing them; the factors contributing to thermal cracks are under study.

NODULIZING

Nodulizing of iron ores has been practiced in Germany since 1914, but the process has not found much application on iron ores in this country. The process is in use at the Extaca plant of Oliver Iron Mining Division, U. S. Steel Corp. located near Virginia, Minnesota. Both hematite ore fines and magnetic taconite concentrates are nodulized. Pulverized coal is burned to provide heat requirements of 2,400,000 BTU's per long ton of nodules from taconite concentrates. Ring formation was a serious problem in the early operations but is now controlled by maintaining stable operating conditions and regular use of the boring bar.

Metallurgical grade manganese nodules are made from manganese oxide flotation concentrates in a plant in Nevada.

BRIQUETTING, EXTRUSION AND CHEMICAL HARDENING

In the briquetting process, the fine particles are mixed with binders, such as cement, and molded under pressure into various shapes. The machine commonly used for briquetting is a double roll with appropriately shaped pockets; the extreme pressures require massive construction. Some of the binders used are starch, cement, lignin products, sodium silicate, lime, and asphalts. Briquetting is used mostly in this country by the chemical and coal industries and has never attained large scale use on iron ores; however, Dravo Corp. is testing a briquetting process on iron ores in a pilot plant.

Iron ore briquetting is done in the USSR by the Russian-Jarcho method which utilizes corrosive binders and pressures up to 50 kilograms per square centimeter. German iron ore briquetting practices use brick type presses providing pressures of 4,300 pounds per square inch. The briquettes are aged for 48 hours at temperatures approaching 100°C. Additives include 3 percent cast iron borings or turnings, 8 to 10 percent coke breeze, and 3 to 5 percent calcium or magnesium chloride as a solution. Fossiliferous red hematite ores of Alabama are successfully briquetted at a pressure of 32,150 pounds per square inch with Portland cement as a binder.

Extrusion-agglomeration has been practiced in the clay industry for more than 50 years and has been suggested for use on iron ores and concentrates because of the low capital outlay and operating costs. The continuous pugmill extruder produces a strong, dense product which can be fired to the required hardness. Fine ores and concentrates can be made plastic enough for extrusion by adding small percentages of bentonite or other agents along with the proper amount of water. The binders must be well pugged into the fine ore and they must not be deleterious to further processing or the final product. In the extrusion-agglomeration of iron ores and concentrates, organic binders which burn out in the blast furnace or open hearth are preferable to those which leave a residue.

A different approach to agglomeration employing chemical action along with pressure is used in the "blocked iron process." Ore fines mixed with salt, cement, chemical binder, and water are pressed in cylindrical molds. The 25-pound blocks are then heat-aged for 12 hours at a low temperature. The high density blocks are suitable for charging the open hearth furnaces because they readily sink through the slag.

Soviet technical literature includes information on investigations of catalytic agents that promote the agglomeration of fine particles by chemical action. The objective of this research seems to be to produce strong pellets without high temperature hardening. Some of the catalytic agents might be used to make stronger green balls and thus reduce the occurrence of load cracks.

OTHER PROCESSES

The drying of iron ores to reduce shipping costs is receiving increasing attention, particularly in Michigan where some of the ores have as much as 17 percent moisture as mined. Interest in dry concentrating methods is growing as a result of the low intensity dry magnetic separators recently developed in Sweden, Finland, and Canada, and the high intensity magnetic separator developed in Germany by which hematite and even limonite can be separated without reduction. The electrostatic process is an other dry separation method that is receiving attention. All these developments lead to the conclusion that drying as a preliminary step in beneficiation will receive more and more consideration.

The roasting of siderite ores has been practiced in Canada for several years. In addition to the beneficiation of iron content accomplished by elimination of CO_2, the process removes most of the sulfur in the ores. Tests performed in Germany on Canadian siderite ores indicated efficient removal of arsenic in roasting in a rotary kiln.

Now that the economics of utilizing the magnetic taconites have become established, attention is turning to the nonmagnetic taconites, semi-taconites, and low grade jasper ores. These nonmagnetic ores are in greater abundance than the magnetic ones. One of the possibilities for treating nonmagnetic ores is roasting to convert the hematite minerals to magnetite. The metallurgical principles have been known for a long time and various processes to accomplish the magnetizing roasting have been tested, but none has proven economic. Increasingly efficient designs for heat conservation in gas-solids reactors along with the availability of better magnetic separation equipment has revived interest in the magnetizing roasting process. Some of the types of equipment that are being tested for this use are the fluosolids reactor, the Lurgi kiln, and the Domnarfvet kiln. The ACL grate-kiln will be competitive in this field too.

An experimental three-foot fluosolids reactor was tested at the Cleveland-Cliffs Iron Company Research Laboratory in Michigan over a period of two years on Marquette Range fine-grained jaspilites. Numerous samples of U. S. and Canadian low grade ores have been sent to Germany for tests in the Lurgi kiln. The Domnarfvet kiln is described in *Transactions of the International Mineral Dressing Congress, Stockholm* 1957 under the title "Magnetic Roasting of Rematite." Magnetizing roasting tests of jaspilite type ores are in progress in a 1½-ton tandem shaft furnace in Australia. A traveling grate roaster of new design has been built and operated at the Mines Experiment Station of the University of Minnesota. Tests of taconite, semi-taconite, and manganiferrous iron ores indicate that magnetizing roasting with this equipment is technically and economically feasible.

Magnetizing roasting studies are underway by Surface Combustion Corp. in a laboratory roaster with a fixed bed using cracked propane for the reduction gas. Precise control of gas composition, gas flow, temperature, and reduction time are maintained. According to their technical literature, the Soviets have performed a large amount of research on magnetizing roasting and part of it was of a basic nature. The kinetics of the reduction reaction have been investigated at low temperatures and pressures, and the effects of the various gases studied; they also have investigated intermediate reduction phases with the x-ray. Magnetizing roasting tests have been conducted by IRSID in France on high grade hematite, low grade minette ores, and chloritic iron ores. These tests provide data about the influence of silica on the equilibrium relationships between the various iron oxides and the metallic iron.

Milling in South America

NORMAN WEISS—AMERICAN SMELTING & REFINING CO.

► At Chuquicamata additional ball mills are being installed to bring about a better balance with the rod mills. The original installation consisted of 10 sections, with one 10½ x 14 rod mill and one 10½ x 12 ball mill in each section. Under the new arrangement each grinding unit will consist of two rod mills and three ball mills, and each mill will utilize four 20-in. hydrocyclones. When the three remaining units are similarly changed, the grinding department will consist of 10 rod mills and 15 ball mills, and it is expected that this program will be completed in 1961.

The results expected from the installation of these five additional ball mills are a 10 pct increase in tonnage and a finer grind of the rougher flotation feed. The latter is expected to bring about better concentrate grade and higher recovery of copper. Additional 8 x 12 ball mills are also being added to the concentrate regrind circuit to cope with the increased tonnage. Ten inch cyclones will be used in conjunction with these ball mills.

► The new El Salvador mill of the Chile Exploration Co. started with one unit of 6000 tons per day, and by late fall 3 units were operating. The ore is said to respond well to flotation concentration, and concentrate grades up to 50 pct copper are being made with satisfactory recoveries. Each section consists of one 10½ x 14 rod mill and two 10½ x 14 grated ball mills, each of the latter operating with four 20-in. hydrocyclones. The rougher circuit features long rows of cells and a good volume of pulp to each row. The cleaner tailing is sent to a scavenger flotation circuit from which it is then rejected as a final tailing. The concentrate flows 16 km through a pipeline to a storage tank at the railroad, and is shipped in railroad cars as a pulp of 60 to 70 pct solids to the filter plant at Potrerillos, and transferred to a tank by an Air-veyor system.

Vibrating feeders are used at both coarse and fine ore bins. Automatic control of grinding will use a non-contacting or isotope type of density controller on the pipeline which returns the classifier sands to the rod mill. The system will be passed upon the assumption that with a constant quantity of wash water makeup the density of this sand-water mixture also will represent the hardness of the ore and will control the tonnage.

Time modulated reagent feeders, centralized on the flotation floor, afford simple process control.

The El Salvador mill has a rated capacity of 25,000 tpd, and it is expected that complete operation will be attained early in 1960.

► The Mauricio Hochschild Co. on the Mantos Blancos copper deposit in Chile has started a 2500 ton per day leaching plant. Leaching will be done by the conventional batch process in vats. Reduction of copper from pregnant solutions will be accomplished by first converting to cupric chloride, then reducing to insoluble cuprous chloride which is then filtered and blended with lime and coke fines. The resultant nodules will be reduced to metallic copper in a rotary furnace, and the metallic product is expected to be of very high purity.

► The Toquepala concentrator of the Southern Peru Copper Co. has successfully passed initial trials, and full production is expected early in 1960. This mill has a rated capacity of 30,000 tpd utilizing seven grinding sections, each consisting of one 10 ft rod mill and two 10½ ft ball mills.

► It is reported from Cerro de Pasco that the five lead zinc and copper concentrators are operating at full capacity with a total daily throughput of a little under 6000 tpd. Their 50-tpd pilot plant is also in operation. Ore from their new Rio Blanco mine has been found highly amenable to conventional flotation practice and the flow sheet of the new 10,000 tpd mill is rapidly taking form. Rio Blanco Mining Co. is a subsidiary of Cerro de Pasco Corp.

Interesting experimentation at Cerro with a 3 ft DSM screen is progressing. The screen was originally purchased to remove tramp material ahead of a cyclone circuit, but lately it has been installed ahead of the primary ball mill to remove all material finer than 8 mesh. The result has been a 10 pct increase of tonnage. It is hoped that the use of DSM screens in this manner will reduce the sliming of galena and thus improve the recovery of lead. Pebble milling is also being examined on a small scale. Hydrocyclones are now operating as classifiers in the primary grinding circuits at the Cerro de Pasco, Mahr Tunnel, and Casapalca concentrators.

► The lead-zinc milling operation of the Compania Minera Aguilar in northwestern Argentina has always been of great interest because of the intimate association of the base metal minerals with gangue. Output is now approximately 30,000 metallic tons per month. The primary grind is relatively coarse, and adequate liberation is accomplished by regrinding the lead and zinc middlings. Classification for regrinding is done with hydrocyclones. Test work using hydrocyclones in the primary circuit is now contemplated.

► The new copper precipitation plant was completed at the Northern Peru Mining Corp.'s Quiruvilca mine early in the year, utilizing conventional vats in place of the former iron launders. This plant treats 180 to 550 gpm of copper-bearing mine water.

► Marcona Iron Mining Corp. is completing its plans for a new beneficiation plant in Peru, and a start of construction is expected during 1960. Several milling plants have been recently completed or will be completed in Peru next year.

► Santander's new 450-ton lead-zinc concentrator principally owned by St. Joe Lead and the Rosenshine interests went into operation in January. The Pacococha 100-ton lead-zinc flotation mill should start operating early in 1960. Condor's new 125-ton copper flotation mill started working early in 1959, and Buenaventura's second lead-zinc mill of 150 tons daily capacity will begin operations early in 1960.

Grateful acknowledgment is made to the following contributors from South America: E. P. Cadwell, B. P. Canning, J. C. Lokken, N. Holme, A. C. Daman, W. H. Lew, H. M. Allen, and D. S. Sanders.

Annual Review — Minerals Beneficiation

CHEMICAL PROCESSING

E. H. CRABTREE—COLORADO SCHOOL OF MINES

The mining industry is becoming more and more aware of the possibilities and need for various types of chemical processing, either in conjunction with, or as an alternate for, the more conventional types of mineral beneficiation.

In the uranium field, new developments included conversion of one section of the Uranium Reduction mill at Moab from acid leaching to carbonate leaching using alkaline RIP in order to treat the high lime ores from the area. The new 522 tpd uranium mill in Wyoming of Federal-Radorock-Gas Hills Partners was scheduled to start operations in November. The process consisted of acid leaching followed by continuous RIP. Another new uranium mill in Wyoming, that of Globe Mining and Union Carbide, was scheduled to start by Jan. 1, 1960. Several producers were investigating the possibility of by-product production, such as molybdenum and vanadium, from the uranium pregnant solutions. Two methods of approach were considered: co-precipitation followed by selective leaching; and liquid-liquid extraction for separation of the metals either from the pregnant solutions, the uranium-barren solutions, or from a bleed stream.

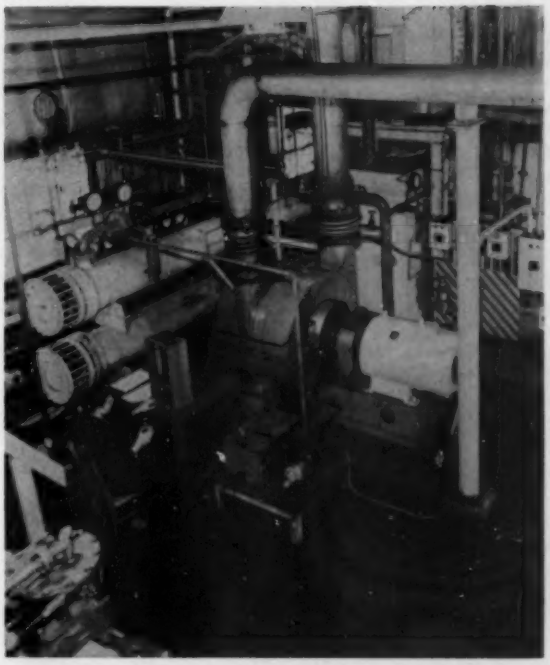
American Potash and Chemical Company was seriously considering recovery of tungsten from its Searles Lake deposit. Although the brine contains only about 70 ppm of WO_3, the amount of brine in the lake is so great that the estimated reserves of tungsten equal the total of all other known reserves in the United States. Several methods of recovery were being studied, including solvent extraction and liquid ion exchange. Precipitation with an organic complexing agent was also being considered.

Miami Copper was planning in-place leaching to recover a large proportion of the remaining copper in the company's mine at Miami, Ariz.

The mill of Union Carbide at Bishop has been modified to incorporate chemical leaching and solvent extraction for the production of high purity paratungstate at the mine. Simultaneously, molybdenum trioxide and calcium tungstate are produced.

Two new processes (which appear to be similar) were described in the literature. One, called Foam Fractionation (*Chemical Engineering Progress*, May 1959) was being developed by Radiation Applications, Inc., New York. The other, called Ion Flotation, was developed by Prof. Felix Sabba, Witwatersrand University, Johannesburg, and has been taken over by Armour & Co., Chicago. (*Engineering & Mining Journal*, Sept. 1959).

In Foam Fractionation, organic reagents and air are applied to dilute solutions of metal salts. Metal values then concentrate in the resulting forth, which is skimmed off for further processing. In Ion Flotation, soap is used as the reagent, and air is bubbled through the solution. The soap apparently reacts with the metal ions to produce a water-insoluble heavy metal soap which floats to the surface and is skimmed off.



Texas Gulf Sulphur Co. and International Nickel Co. of Canada have announced "encouraging results" in eight-months operation of a pilot plant for obtaining pure sulphur from SO_2 in the roaster off-gas at Inco's iron ore recovery operation at Sudbury.

Among the Bureau of Mines reports issued during the year was one (RI 5442) on acid-ferrous sulphate leaching of low-grade manganese carbonate and oxide ores, another (RI 5469) on volatilization of tin chloride from Bolivian slimes, and another (RI 5465) on conversion of Nicaro nickel oxide to nickel metal. A new method, developed by the Bureau, produces commercial-grade tungsten and molybdenum powders by fused-salt electrolysis and was tested successfully on scheelite and powellite.

An article by Robert H. Raring and G. Y. Murray (*Engineering and Mining Journal*, Aug. 1959) forecasts the design of gold plants of the future, and points out the possibilities of utilizing the many technologies we have learned in uranium processing.

Among the many patents issued was one to Zimmerley and Prater of Kennecott for the recovery of rhenium by ion exchange from solutions obtained by leaching flue dusts derived from the roasting of certain molybdenite concentrates.

Materials Handling

C. F. GOLSON—WEMCO DIV.

Most efforts in materials handling during 1959 were concerned with reduction in man-power, more efficient use of known principles and devices, and better blending of raw materials fed to processing plants.

Weighing: Most mill men have deplored the time lost in calibrating and checking automatic belt conveyor weighing devices. The use of multiple integrating devices on the same belt, though somewhat more costly to install, has reduced elements of error and lost time, since a simple comparison will readily indicative defective or inaccurate weighing devices and, therefore, limit time and effort to actual malfunctions.

Conveyors: Coal washing plants were among the first to extend the use of cable suspended conveyors to the handling of materials above ground. Results obtained in those cases, in particular, where long spans have to be covered, may lead to changes in design from truss supported conveyors. The use of cable or flexible supports for idlers, also derived from mining practice, has been tried with varying results; most of the difficulties being due to the abrasiveness of the material being conveyed. Improvements in belt design and manufacture have led to longer life. A recent development is the belt with a formed border, molded integral with the cover: this holds the material on the flat belt, reducing breakage of the reinforcing fabric at those points where the belt is troughed and eliminating costly troughing idlers. This molded head collapses and flattens out when the belt passes over head or tail pulley.

Materials Handling Equipment: Use of heavy dirt moving equipment, mostly on rubber wheels, with their great flexibility and low operating cost is beginning to become a factor in mineral processing plants.

Control of Tailings: Use of emitted X-rays to "assay" up to five elements in suspensions of metallic ores or tailings flowing through pipelines or launders, can be considered as a great step forward in automation of the milling process leading to reductions in the human element involved in sampling and chemical analyses.

Control and Bedding of Raw Materials: The bugaboo of all processing engineers always been variations in feed, both in tonnage and in content of the raw material. Great progress has been made by applying existing devices to this problem. Anaconda in the metallic ores and American Cement Company have adapted to Mineral Beneficiation, and perfected according to their specific requirements, schemes and systems used in other metallurgical industries such as the steel industry.

Pumping of Slurries and Pulps: Unremitting efforts on the part of pump manufacturers, and increasing demands of the users, have led to applications undreamed of only a few years ago. Better knowledge of the properties of materials and of slurries in motion have resulted in higher heads, higher densities, and improved efficiencies.

In general, it may be said that 1959 was not a year of revolution, but of evolution. With increased costs and lower prices of most mineral products, with reduced activities caused by depressed markets or by strikes, there has been a slow-up in new designs and a consolidation of progress in the recent years to obtain greater efficiencies at lower costs in power and labor.

Wider use of dry cement transport is seen, and 47 other products have so far been found suitable. Produced by Delta Tank Mfg. Co., this highway transport has a low pressure blower discharge.

Part of the world's longest permanent cross country transport belt conveyor, 5⅝ miles long, which serves Ideal Cement Co. at Ada, Okla. Link-Belt Co. built the 1000 tph system.

OPERATING CONTROL

L. A. ROE—INTERNATIONAL MINERALS & CHEMICAL CORP.

Highly automated rockets are daily exploring the new worlds of outer space while automation of ore-processing plants continues to plod ahead at an earthly pace. However, the outer space exploration program will have an effect on the mineral processing industry. Some of the new control equipment developed for rocketry is bringing new concepts and techniques to automation of mineral plants. In the electronics industry the transistor has revolutionized the engineers' approach to circuit design problems. Instruments and circuits previously considered impossible have become reality. With these new tools, the automation of mineral processing plants should begin to move ahead at an increased pace.

An outstanding article covering instrumentation and computer control appeared in *Chemical & Engineering News*, July 13 and July 20, 1959 issues. These articles listed most of the major equipment manufacturers and the types of equipment they produce. The dollar volume of business for the major equipment instrument manufacturers is listed for the years 1955 through 1958. It is interesting to note that the chemical process industry spends 52.8 pct of its intrument dollar for temperature and pressure instruments. The balance is divided between flow meters, liquid level instruments, composition and consistency instruments, weighing and proportional instruments, air and miscellaneous measuring instruments. The U. S. Dept. of Commerce reports that overseas demand for U. S. industrial instruments has steadily expanded over the past few years in spite of steady growth in foreign production. Overseas sales of U. S. instruments reached a new high of approximately $231 million in 1958 in contrast to only $128 million in 1955.

In the specific mining field, the outstanding advances in operating control in 1959 have been in automatic analytical methods of mineral products. X-ray fluorescence methods are meeting with outstanding success in several areas. R. E. Wood, of the Kennecott Research Center discussed general potentials of the method in the June 1959 issue of MINING ENGINEERING. Messrs. Holderreed and Lucy reported outstanding success in continuous assaying of copper pulps in an Anaconda plant at the American Mining Congress in Denver in September. For those readers unfamiliar with X-ray techniques, Dr. Holderreed's description of the basic X-ray principles involved is repeated here:

"Under suitable current conditions, the target of an X-ray tube emits a beam of high intensity X-rays. These primary X-rays fall onto the sample to be assayed and, within the energy limits of the primary X-rays, excite the atoms of the various elements in the sample. In turn these excited atoms emit (or fluoresce) secondary X-rays, each element at a wave length characteristic of that element (e.g. copper, iron, sulfur, or or silica in the present discussion). A selected portion of the secondary X-ray beam is caused to fall upon a diffraction crystal by means of collimator, slit or similar device. The function of the crystal is to sort out and pass only the energy beam of interest, e.g. copper. This 'sorted' or diffracted beam is caused to enter a suitable detector where the fluorescent energy is measured. Theory shows that the energy intensity of the diffracted beam of secondary X-rays is proportional to the quantity of element in the sample. It is no great problem, therefore, to determine the copper in an unknown sample, if the energy read-outs of similar known, or standard samples are available: the copper concentrations will be proportional to the strength of the fluoresced and diffracted beam of X-rays."

At Louisville Cement Co.'s Speed, Ind. plant, Leeds & Northrup electric load controls maintain optimum grinding rates for the ball mills.

Anaconda has successfully applied X-ray techniques to the continuous monitoring of mill pulps extending from the copper concentration levels of final concentrates (22 to 32 pct copper) to bulk tailings at 0.10 to 0.25 pct copper.

From Finland, the use of X-ray fluorescence techniques is reported in use for on the line analysis of titanium in ilmenite. A paper on this application was presented at the February 1959 AIME Meeting in New York by E. A. Laurila, Lauri Saari, and Olli Castren.

As has been the case in practically all automatic analytical devices applied to ore pulps, the technique of obtaining an accurate, representative sample has been the most difficult portion of the problem. Anaconda Engineers utilize a plastic sample cell after vibrating screens remove wood fibers and appropriate care has been taken to eliminate air bubbles. The Finnish analyzer utilizes a miniature drum filter with a diameter of 30 centimeters, a length of 10 cm and a rotation of 2 rpm. As the sample reaches the highest point on the drum, it is radiated by the X-rays. After analysis, the sample is washed off by a water spray. Repeated successes in the field of X-ray analysis of mill pulps indicate that this method will gain rapid acceptance in many operations.

Progress is being made in the solution of two control areas vital to metallurgical plants. One of these is continuous analysis of moisture content. A technique developed jointly by General Motors Research Laboratories and General Motors Foundry Engineers is continuously measuring moisture content of foundry molding sand. The technique involves use of a neutron emission source, plutonium —239. The Schlumberger Co. has produced an analyzer for moisture content of granular solids with high accuracy. The second area of in milling control which seems to be approaching real success is that of analysis of subsieve particle size. One of the most promising analytical methods is the Coulter Counter for particle content and size distribution, manufactured by Coulter Industrial Sales Company, Elmhurst, Ill. The method involved is applicable to sizes from about 0.5 microns to about 500 microns. The apparatus determines the number and size of particles suspended in an electrically conductive liquid. As this liquid flows through an aperture with a simultaneous flow of electric current, a series of electric pulses result. Each pulse is proportional in magnitude to the volume of the particle causing it. The pulses are amplified, scaled, and counted to provide direct data for plotting cumulative particle frequency against particle size. This apparatus is already in use in one of the leading iron ore research laboratories and has found use in many ceramic, cement, and chemical research laboratories.

The use of infrared techniques is growing rapidly in the process industry. Continuous monitoring of heat treating atmospheres through use of infrared analyzers and recorders has been used for sometime by the metallurgical industries. The industrial infrared gas analyzer includes two basic components, an analyzer cell located at or near the furnace, and a recorder which can be mounted in a central control room. Measurement is based on the fact that different gas compounds in a mixture absorb radiation from different parts of the infrared spectrum. Thus, each compound can be identified on the basis of its infrared energy absorption.

Also at the February AIME Meeting, Messrs. Mitchell, Berman and Goldberg of the Radiation Electronics Co. reported on use of infrared techniques to measure temperatures from remote locations. The sensitivity of radiometric equipment (infrared) can be dramatically demonstrated by a comparative photograph and thermograph of the human face. A thermograph, by black and white contrast, shows a difference of two degrees centigrade and thereby effectively outlines the human face. One of the main advantages of the infrared detector in measuring temperatures is that no direct connection of the instrument to the surface being measured is required. Any distance over four feet is satisfactory. Some of the applications already in use include temperature measurement of moving sheets or strips of paper, rubber, glass, metals, and rotating objects such as motors and turbine blades.

The elaborate instrumentation of the Homestake-Sapin Partners uranium mill near Grants, N. M. was described in detail by Allen, Malmberg and Hansen in the June 1959 *E&MJ*. In all 31 control points are described. At this plant process controls and electrical controls have been integrated into a logical arrangement specially designed for ease of operation.

Magnetic flownmeters continue to find increased acceptance by the mineral industry. Active competition between instrument manufacturers has resulted in improvement at reduced costs. The total market for primary flow measurement elements has reached $20 million a year, according to a recent estimate.

The September 1959 issue of *Rock Products* reports an example of tomorrow's instrumentation and automatic control in the cement industry. A Finnish cement plant automatically recovers saleable potash dust from a rotary cement kiln. The radioactive properties of potassium are utilized by measurement of potassium isotope (K^{40}) in the kiln dust. The dust is automatically recycled to the feed end of the kilns at any value below about 7 pct K. Above this value, the dust product is automatically sent to shipping bins as a saleable product. International Minerals & Chemical Corp. has utilized a radiation method to assay the potassium content of feldspar and sylvite products for several years.

The Riverside Cement Co., Oro Grande plant near Victorville, Calif., has taken another step forward in computer control of the cement-making process. Important control features include:

1) A digital computer which calculates quantitatively what kinds of raw materials must be stockpiled and blended to obtain proper proportions of kiln feed.
2) A high-speed pneumatic tube system which carries raw material samples in cartridges from the sampling area to the laboratory in a few seconds.
3) An X-ray spectrometer for rapid, accurate analyses of raw materials.

The first installation of Hewitt-Robin's new bucket wheel rotary reclaimer can remove stockpiled materials at rates of 300 to 500 tph. This new machine should find application in many similar stockpile systems.

Instrumentation has been defined as "the art and science of measurement, control and analysis of physical conditions." Automation has been defined as "a system in which effect is controlled within the desired limits by reflexive regulations of cause." Summation of these definitions outlines one of the modern minerals process engineer's primary goals—low cost control of minerals processing operations.

ANNUAL REVIEW

U. S. BUREAU OF MINES ACCOMPLISHMENTS DURING FISCAL 1959

Highlighting the Government's programs for metals, nonmetallics, and mineral fuels during a period that saw increasing supplies of essential materials, the Secretary's report notes the following outstanding accomplishments:

Coal: The Bureau began an ambitious study to determine whether hydraulic methods can be employed successfully in the United States to mine bituminous coal. Another new project seeks techniques for removing explosive methane gas from coal seams in advance of mining. Anthracite research included an experiment in mining a thick, moderately pitching vein of coal mechanically, and continuation of a full-scale longwall mining test.

Coal-preparation studies emphasized improvement of methods for cleaning bituminous coal, especially the fine sizes that usually do not respond well to mechanical treatment. Nuclear radiation also was used to gain more knowledge of the fundamental properties of both bituminous coal and anthracite.

Petroleum and Natural Gas: The Bureau participated in long-range cooperative studies to estimate future requirements of these fuels and outline ways of assuring supplies. Oil and gas technology moved ahead with Bureau development of new production methods, improved instrumentation, and more accurate techniques for determining basic characteristics of hydrocarbons.

Health and Safety: A Bureau-devised, portable mining shield was made available commercially, and a pocket-sized methane detector was developed. Cooperative studies with industry moved closer to an automatic methane-monitoring system for use on electrical equipment in coal mines.

Production of safety-education films for mineral-industry workers was intensified, and approximately 10,000 persons completed the Bureau's various accident-prevention courses. The Bureau's 246 Federal inspectors made nearly 12,000 inspections of the Nation's coal mines.

Helium: A fifth Government helium plant, designed to produce 290 million cubic feet of helium annually, neared completion at Keyes, Okla., promising an adequate supply of the lightweight gas, at least temporarily. Simultaneously, the Department of the Interior renewed its request for legislation that would encourage private industry to build and maintain up to 12 new plants to recover huge quantities of helium now lost when it goes to fuel markets as a constituent of natural gas.

Metallurgy: Pioneering experiments by the Bureau of Mines created shaped molybdenum castings that are expected to speed space exploration and missiles development. High-purity tungsten and yttrium metals were obtained by Bureau metallurgists on a laboratory scale, new economies were attained in hafnium production, and the Bureau began a commercial evaluation of its electrolytic process for recovering high-purity titanium from scrap and other materials.

Other Bureau attainments in this field were successful experiments in which both coal and natural gas were used as iron blast-furnace fuels, and production of low-nickel austenitic stainless steel from offgrade ores. Research on nonmetallics advanced with studies of super refractories, elemental boron, and asbestos.

Mining: New knowledge was gained in studies of blasting techniques and rock breakage, and progress was made in research to find ways of utilizing submarginal phosphate-rock deposits.

Foreign Activities: Bureau specialists gave technological aid in mineral development to 15 friendly countries, and 25 foreign scientists and engineers trained at Bureau establishments during the year.

ANNUAL REVIEW

U. S. GEOLOGICAL SURVEY REPORTS FISCAL 1959 ACCOMPLISHMENTS

Increased mapping activities, widespread investigations in geology and water resources, and new production highs from mineral and petroleum leases on public lands are recorded by the Geological Survey in its annual report for fiscal year 1959.

During the year the survey marked its 80th anniversary (March 3, 1959). In topographic mapping, activities were carried on in every state, the District of Columbia, Puerto Rico, and the Virgin Islands. A total of 2,439 maps were prepared for printing and distribution, of which more than 1600 constituted new mapping. A stock of some 30 million maps—about 21,000 different quadrangles—is available now, covering nearly half the total area of the United States. Nearly 355 permanently marked triangulation stations were established to provide control for areas totaling more than 30,700 square miles. A new 1:500,000-scale map of Tennessee was published and compilation is in progress on new state maps for Maine, Minnesota, Montana, Nebraska, Nevada, North Dakota, South Dakota, Utah, and Washington. Cooperative programs totaling $4 billion were in effect in 34 states, Puerto Rico and the Virgin Islands, the Federal Government meeting half their cost.

Continuing investigations and appraisals of United States geologic and mineral resources through comprehensive research programs, Survey geologists carried on approximately 425 active projects. Results of geologic investigations were reported in 27 professional papers, 65 bulletins, 91 maps and 2 circulars published by the U. S. Geological Survey, in 43 reports released in open file, and in approximately 250 articles published in scientific journals.

New geophysical data about large areas of the country were provided through airborne radioactivity and magnetic surveys. Several new geologic, geophysical, and geochemical studies were directed toward the discovery of concealed ore deposits. Geologic mapping and stratigraphic studies designed to aid exploration programs in the mineral fuels field were in progress in 30 states and survey scientists participated in a special study of the Nation's productive capacity of petroleum through 1975.

Water resources investigations included the systematic collection, analysis, interpretation and publication of hydrologic and related geologic data. Streamflow data were obtained from about 7,100 gaging stations. Some 640 ground-water investigations were in progress and sediment and chemical quality studies were in progress throughout the country, covering the most important river basins and ground-water aquifers.

Survey conservation activities were aimed at assuring proper development and use of water and mineral resources on federally controlled lands. This work required field surveys; preparation of maps and reports dealing with water power, fuels, minerals and chemicals; and on-site supervision of mining and drilling operations.

Approximately 33,623 cases concerned with mineral classification were handled; a total of 400 miles of stream channel surveys and 9 dam site surveys were investigated; 4,018 mining properties were supervised, involving leases, permits, and licenses in 34 states; and about 151,000 supervised oil and gas properties gave appreciably greater yields than in the previous fiscal year.

ANNUAL REVIEW
1959 MINERAL PRODUCTION

Preliminary Figures

Despite a slight rise in the total value of mineral output in the U. S. in 1959, a number of commodities—principally metals where strikes suspended operations—did not follow the upturn in economic activity, the USBM reported in a year-end summary.

The Bureau, in preliminary figures, estimated the value of mineral production for 1959 at $17.1 billion, compared with 1958's $16.5 billion. The record, $18.1 billion, was established in 1957.

The Bureau said the 1959 total value of all minerals, including fuels, was 2 percent higher than in 1958, due largely to increased production in certain lines, since unit values were mostly steady. The few price increases for some products were offset by decreases in others. Nonmetal construction materials, crude petroleum, and natural gas contributed most of the increase in total value. Total value of fuels output rose from $11.6 billion in 1958 to $11.9 billion in 1959.

Down: Among the materials registering declines in total value in 1959 were lead, fluorspar, silver, iron ore, anthracite coal, manganese ore, mercury, copper, gold, and chromite. Strikes in steel and copper were the principal factors in decline in value of metals output, from $1,597 million in 1958 to $1,550 million in 1959.

Up: Large increases in the mining of uranium ore, bauxite, and molybdenum compensated for part of the reduced value for other minerals. Copper, lead, and zinc quantities dropped, but the combined total value rose slightly because of higher prices.

Mine and quarry production of nonmetal construction minerals was higher. Stone, sand and gravel, clays, and cement gained from 10 to 15 percent. Output of chemical mineral commodities and fertilizer materials also was larger. The value of nonmetals output was $3,690 million, compared with $3,340 million in 1958.

Bituminous coal and lignite production in 1959, estimated at 410 million tons, was the same as for 1958. The expected gain for 1959 did not materialize

because of the steel strike. The outlook at year's end was for an improved coal market in 1960. The average value of soft coal at the mine was estimated at $4.86 a ton, unchanged from 1958. Pennsylvania anthracite production was estimated at 19.5 million tons, an 8 pct decrease from 1958.

Industrial Minerals: Construction established a new record in 1959, increasing about 15 pct over 1958 despite the steel strike, shortages in highway building funds, and difficulties in home financing. Output of stone, sand, and gravel in 1959 paralleled the upward construction trend and reached new highs.

Blast-furnace slag for use in portland cement was in high demand, but an acute shortage developed because of the steel strike. Increased construction activity resulted also in greater demand for cement, and production in 1959 was 9 pct higher than in 1958 and 4 pct higher than the 1956 peak. Four new cement plants were built and others were expanded. Annual capacity reached 410 million barrels. Gypsum and gypsum products neared new highs because of residential construction.

Clay output increased about 10 pct because of greater demand for refractories, a continued high level of activity in the building industry, and the development of new processes for making clay-bonded lightweight building block. Talc, soapstone, and pyrophyllite production showed a gain of about 2 pct. Feldspar output was about the same as in 1958. Sales of natural and artificial abrasive materials advanced at least 25 pct during 1959 as manufacturing rebounded from 1958 declines.

Domestic fluorspar production in 1959 was 180,000 short tons—the lowest in over 20 years. Production of phosphate rock and potash increased 3 and 10 pct, respectively, over 1958. Domestic production of Frasch sulfur was about the same as 1958. Lime output reached a record high and was 17 pct above 1958. Reversing the downtrend of the past 3 years, salt manufacture in 1959 gained 8 pct over 1958.

Copper output from domestic mines in 1959 dropped approximately 16 pct to the lowest since 1949 because of work stoppages that began in August at many of the principal copper-producing properties. Refined copper output from primary and secondary materials was similarly affected by strikes and fell about 17 pct. Producers' stocks were the lowest since 1954 and were 48 pct less at year's end than in the beginning of 1959. Total imports of unmanufactured copper rose about 10 pct, whereas exports of refined copper dropped aproximately 40 pct. Consumption of refined copper rose about 10 pct.

Lead and Zinc: Consumption of lead and zinc in the U. S. increased significantly in 1959. Strikes, however, restricted refinery production and caused heavy withdrawals from inventories. Low metal prices and strikes dropped domestic mine output of lead to 251,000 short tons, the smallest since 1900. Domestic mine production of zinc was at a high rate in the first half of the year, but fell sharply during the last half because of strikes and output was the same in 1958.

Iron Ore: Largely as a result of the 116-day steel strike, U. S. iron ore output of 60 million tons was the lowest in 20 years. This decline was almost wholly responsible for the overall drop in the value of the metal component of domestic mineral production in 1959. While domestic output was dropping, imports of iron ore gained. On the basis of 9-months' figures, the Bureau estimates imports for 1959 will approach 35 million tons and thus break the 1957 record. Despite the steel strike, the Bureau estimates that 1959 pig-iron output (60 million short tons) and steel (92.5 million tons) will surpass 1958. They will, however, be well below 1957.

Primary aluminum production in 1959 was a record 1.95 million tons, a 25 pct increase over 1958 and 16 pct greater than in 1956, the previous high year. Domestic production of bauxite in 1959 was approximately 1.5 million long dry tons, a 14 pct increase over 1958. Imports of bauxite were estimated at 8 million tons, about the same as in 1958.

Primary magnesium production in 1959 was 31,000 tons, an increase of 1,000 tons over 1958. Shipments of 46,000 tons were up 35 pct. Output of magnesite and dolomite for basic refractories in 1959 was 4 million tons, a 38 pct decrease from 1958. The drop was due primarily to the steel strike.

Titanium: Production of about 4000 short tons of titanium sponge metal during 1959 was slightly below 1958's. Consumption was approximately 3,200 tons or 1,000 tons less than in 1958. Domestic production of ilmenite was approximately 600,000 short tons, 6 pct higher than in 1958, but rutile output was only 2,000 tons, or about one-fourth the 1958 total.

Mercury: Domestic mine production of mercury in 1959 declined for the first time since 1950. Total production was 31,500 flasks, nearly 20 pct less than in 1958.

Molybdenum production gained despite strikes at several copper plants that sharply curtailed the output of byproduct molybdenum. **Tungsten** was produced in 1959 by only two mines—the Pine Creek mine of Union Carbide Nuclear Co. in California and the Climax mine of American Metal Climax, Inc., in Colorado. **Chromite** production declined about 20 pct.

Precious Metals: Mine production of gold and silver in the United States continued to decline in 1959 and output of gold was approximately $54.8 million, a drop of about 10 pct from the $60.8 million of 1958. Silver output was approximately $27.1 million, about 12 pct lower than 1958's total of $30.9 million. Output of platinum-group metals recovered from domestic placers and from byproduct sources was the lowest since 1940.

Uranium ore production in the United States totaled about 6.8 million tons, valued at over $140 million, compared with 5.2 million tons, valued at $116 million, in 1958.

Mine shipments of rare-earth metals and thorium ores and concentrates in 1959 totaled about 1,800 short tons, valued at $318,000. Of this total, 1,280 tons of monazite, bastnasite, and euxenite concentrates contained an estimated 700 tons of rare-earth oxides.

ANNUAL REVIEW

MINING SYMPOSIUMS

• *Growth of university sponsored technical symposiums has been one of the most heartening signs of long range health for the mining engineering profession. Devoted to reports of research, of development, and airing of problems susceptible to research attack, these meetings have provided cross fertilization and exchange of ideas between campus, factory, and the mining industry itself. Interest on the part of, and attendance by, men from the mining industry has been strong, and growing stronger.*

• *In 1959 the round of these meetings in the U. S. began with one of the most long established, the 20th Annual Mining Symposium at Duluth, sponsored by the University of Minnesota, and held the same week in January as the annual Mid-Winter meeting of the AIME Minnesota Section. Others during the year included the Fifth Annual Symposium on Mining Research sponsored by the University of Missouri School of Mines and Metallurgy and the U. S. Bureau of Mines, and the Ninth Annual Drilling Symposium. The Drilling meeting represents an interesting joint activity by Colorado School of Mines, the University of Minnesota, and Pennsylvania State University resulting in continuity and rotation of a series of meetings on different mining themes. Not university sponsored was the notable conference "The Undiscovered Earth" prepared by Southern Research Institute. This conference dealt broadly and inspirationally with our natural resources and natural heritage, the earth.*

• *In Europe two major meetings have been devoted to Rock Mechanics in recent years, and this year the Institution of Mining Engineers sponsored a major symposium on Shaft Sinking and Tunneling, held in London in July. More about two of these conferences on the following pages.*

SHAFT SINKING

AND TUNNELING

In London, during July 1959, the Institution of Mining Engineers organized a Symposium on Shaft Sinking and Tunnelling. Formally opened by Sir James Bowman, Chairman of the National Coal Board, the symposium was held at Olympia at the same time as the exhibition of mining machinery sponsored by the Council of Underground Machinery Manufacturers. For the three-day symposium, the IME received nearly 800 registrations and it is reported that the average attendance at the various sessions was about 400. Of the delegates, 200 came from 32 countries outside Great Britain.

At 11 discussion sessions, some 25 technical papers were presented, these having been prepared by authors from 14 different countries. The major contribution was from Great Britain with five papers, followed by Belgium with three, while those countries from which two papers were received comprised Canada, France, Germany, Poland and South Africa. Single papers came from Australia, Czechoslovakia, Holland, Hungary, Sweden, U.S.A., and the USSR. Simultaneously translation facilities were provided so that those attending could follow the proceedings in English, French or German and, after brief introductions by the particular authors, the bulk of the time available was devoted to discussion of the various papers. It is understood that a bound volume containing the full proceedings of the symposium will be available in due course at £3 (plus 2s. for packing and postage) from the Secretary of the Institution of Mining Engineers, 3 Grosvenor Crescent, London, S.W.1.

During the course of the symposium many films were shown of tunnelling and shaft sinking operations in different parts of the world, including Great Britain, South Africa, Russia and Europe. Also several films were seen illustrating the application of mining machinery manufactured in Great Britain and elsewhere.

At the conclusion of the sessions (of which five were devoted to tunnelling, and six to shaft sinking), a summary was given by Mr. H. E. Collins, C.B.E., Chairman of the Symposium Committee, followed by the closing address by Mr. T. A. Rogers, C.B.E., President of the Institution of Mining Engineers.

With regard to rates of sinking progress, it was recently reported that a Russian record of 868 ft in 30 days set up during April of this year in a 21½ ft diameter shaft in the Don coal field was exceeded this September by a South African company. At the Anglo American Corporation's Vaal Reefs No. 2 shaft (26 ft in diameter) an advance of 922 ft was achieved during September with a team of 48 Europeans and 353 Africans working in four shifts throughout a 24-hour day.

DRILLING SYMPOSIUM

The ninth annual Drilling Symposium was held this year (1959) at Pennsylvania State University, cosponsored by that school, the Colorado School of Mines and the University of Minnesota. The theme was "Exploration Drilling" and representatives of almost every major maker of equipment in the field were present. Of interest was the attendance of a number of men from the petroleum industry.

A wide cross section of mining districts were also represented, and all three groups, campus, manufacturer, and miner alike participated actively.

Improving Core Recovery was the topic of the first session. Apparently the agreed-on first step in this direction was to improve relations between contractor and mining concern, particularly as regards frankness of demands for performance, and intent to produce. Law reared its ugly head as the drilling contract as a device toward better contractor-miner relations was explored. Company personnel reported encouraging improvements in core recovery following these steps: frank statement of performance expected, willingness to pay for care, careful expression of goals and prices in a fair contract, and finally full-time, competent representation at the hole being drilled. In fact, technical methods of improved core recovery took a second place to better human relations in realistic solution of the problem, to judge by remarks from both speakers and discussors.

Statistics and Operations Research in Exploration held high audience interest and active participation in an evening round table discussion. Comment drew a clear picture that mounting costs coupled with harder search conditions have made exploration personnel eager for better tools than hunch, custom, or systematic and expensive grid drilling for finding and delineating ore bodies. Whether or not operations research can provide practical answers at this moment was still viewed skeptically, but the skepticism more directed at how soon these tools could be of help, than whether ultimate progress was possible.

One speaker asked as many questions as he answered, probing to find what level of information existed about ore occurence. Off the platform this man from outside the minerals industry ventured the opinion that geologists were modest in estimating the state of their art, and that sufficient knowledge existed, or would soon exist, for initial application of search theory. He proposed that the first useful application would be in the efficient blocking out of an already located orebody. That experience with this type of project would ultimately pave the way for more sophisticated problems, such as speculative regional studies.

Slim Hole, Large Hole, and Air Drilling was the theme that brought out equipment reports and evaluation. Among the papers was one "reassessing" the merit of small-diameter drill holes. It was soon clear that this was in the sense of the scale of the petroleum industry, not mining. In essence, that perhaps 4½ or 6 in. holes were faster and cheaper, while still adequate for all but the maximum levels of production. Other topics included papers on horizontal boring of holes for subsurface utility installations, development of large-diameter rotary drilling machines for shaft-scale workings, and use of foam agents in drilling.

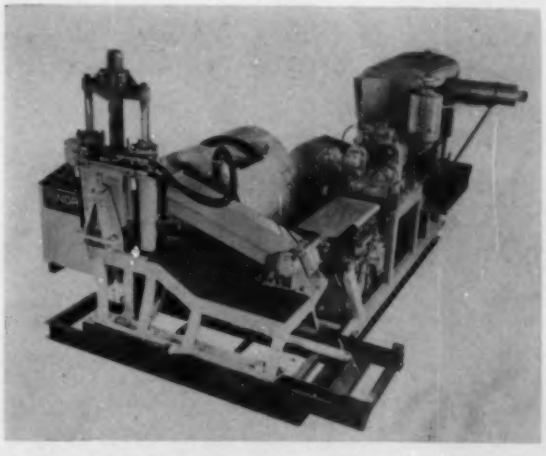
Bit Design and Use of AM-9 for soil and earth stabilization were the final topics considered. Canadian experience with the polymer material were covered as well as the general technique. Cost consideration and specialized limiting conditions restrict the material from the widest possible use, but spectacular successes where grouting and other techniques had failed offset the occasional failures and the complications and costs in its use. In brief, it looks possible to cement, or rather polymerize, almost any unconsolidated material, and to fill major cracks in more solid materials, providing there is not too much water flow, and one can deliver the material to the trouble site.

On the final day of the meeting an interesting paper revealed the techniques for exacting surveying of bore holes developed by the Swedish Diamond Drilling Co. Rapid, but high order plotting resulted from the use of this specialized equipment.

Largest Diamond Drill in the World

Mindrill Ltd., Melbourne, Australia, recently completed the largest diamond drill in the world. Capable of drilling vertical or angle holes to depths in excess of 10,000 ft, the rig operates with a tiltable frame 72 ft high and capable of handling 60 ft of drill rods per lift.

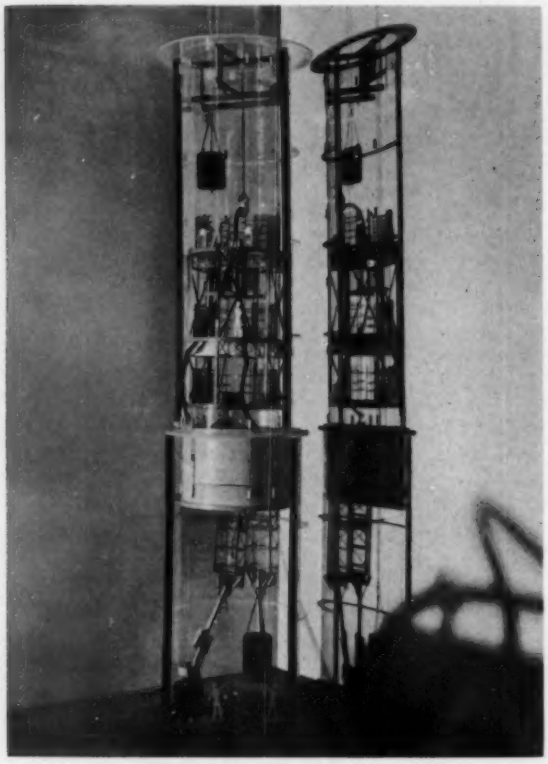
Two hydraulic cylinders combine functions of thrusting and tilting. Power is transmitted through a torque converter and hydraulic powershift gearbox giving speeds from 200 to 1500 rpm. The hoist provides direct line pull of 50,000 lb with speeds to 300 fpm. A 176 hp diesel with four separate power takeoffs drives head, hoist, hydraulic pump, and air compressor. First jobs for the big machine will be at Kalgoorlie Southern Gold Mines.

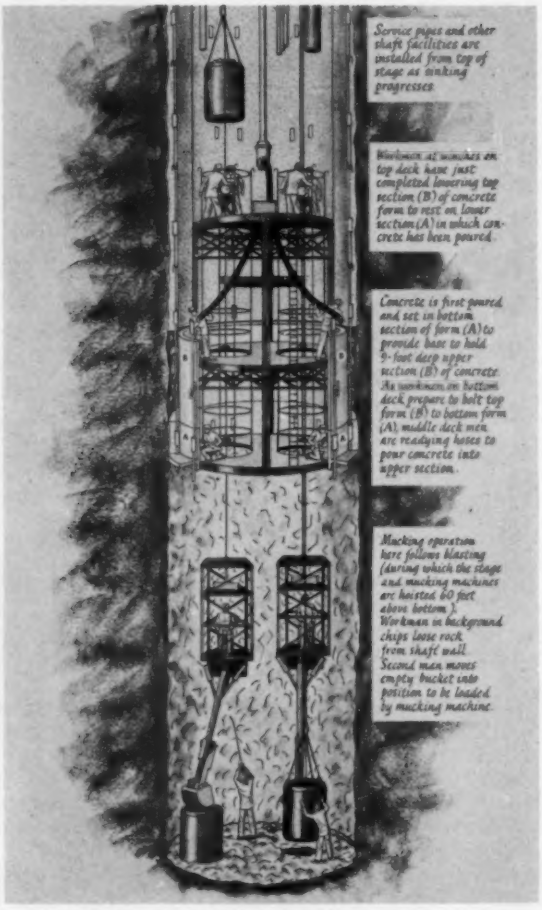


MINING IDEAS

Just as ore dressing made contribution of most of the unit operations to chemical engineering and sanitary engineering—so also has mining returned its share of ideas to other industries. Freezing shafts is neither new, nor common, but has recently been applied to putting in a shallow shaft for a major sewerage tunnel in New York City. The ideas on these two pages are mining's own . . . as yet.

FROM IMC




Service pipes and other shaft facilities are installed from top of stage as sinking progresses.
Workmen at numbers on top deck have just completed lowering top section (B) of concrete form to rest on lower section (A) in which concrete has been poured.
Concrete is first poured and set in bottom section of form (A) to provide base to hold 9-foot deep upper section (B) of concrete.
At workmen on bottom deck prepare to bolt top form (B) to bottom form (A); middle deck men are readying hoses to pour concrete into upper section.
Mucking operation here follows blasting (during which the stage and mucking machines are hoisted 60 feet above bottom). Workman in background chips loose rock from shaft wall. Second man moves empty bucket into position to be loaded by mucking machine.

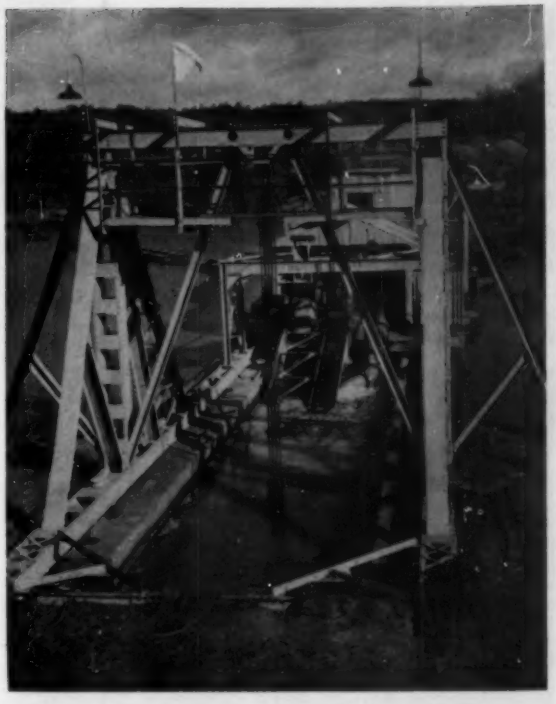
Ingenious Time-Saver for deep mine shaft sinking is being built for use by the Canadian subsidiary of International Minerals & Chemical Corp. to complete a 3,000-ft shaft at its potash mine project in Saskatchewan, Canada. The mobile *triple-decker* arrangement allows simultaneous activity at three levels in the main phases of shaft sinking—mucking or digging, preparation of concrete forms, and the pouring and finishing of the concrete shaft lining—and can make sinking three times faster. The entire unit, including the mechanical diggers, moves up and down the shaft. This is the first use of this triple-decker principle in the Western Hemisphere. Similar operations have been employed with great success in deep-shaft sinking for South African mines. The IMC mine, near Esterhazy in eastern Saskatchewan, will produce from the world's greatest known reserve of high grade potash ore. Model is shown at left, diagram at right.

FROM MINNESOTA

In an unusual iron mining operation at Jessie H. Mine, Grand Rapids, Minn., the Hallett Construction Co., is employing a dredge to strip overburden from a portion of the iron ore deposit.

On the front of this dredge is shown a heavy duty model Swintek dredging ladder manufactured by Eagle Iron Works. This device has a special chain which travels over the intake nozzle thus acting as a screen so that boulders and stumps cannot get into the suction line to cause clogging, or damage to the pump. Cutter bars mounted at intervals on the traveling chain pick up boulders, carry them up the ladder and dump them away from the pumping zone. These same cutter bars serve to agitate the deposit, loosening up the overburden so as to increase ratio of solids to water pumped.

The intake end of this Eagle Swintek dredging ladder can be lowered to an effective digging depth of 55 ft. Suction line is 16 in. diam.



FROM SWEDEN

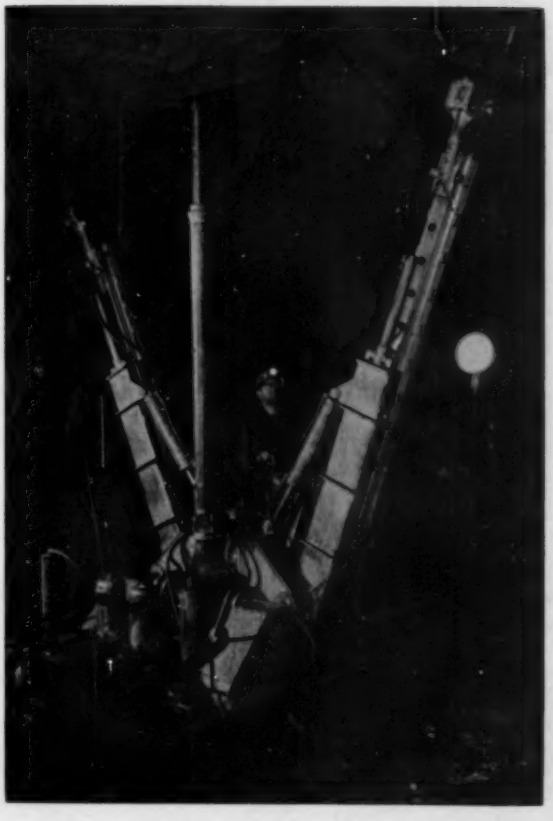
Underground mining has witnessed a host of ingenious new devices to mechanize, eliminate, or speed up old underground mining jobs. Shaft sinking, as at right, has witnessed loader development, better drifting tools have come along, and now raising is getting attention.

Sweden which has contributed more than its share of trends and ideas to mining in recent years, has come up with two more devices or techniques.

One, the Raise-Climber, is now being imported to the U. S. by Alimak Corp. of San Francisco. This unit makes possible, where ground permits, driving untimbered raises to heights of 450 ft. Either compressed air, or electric drive, the machine traverses the raise on a special track bolted to the wall. The frame which carries the miner, drills, etc., travels along the rack at 33 fpm, and air, water and any other lines are carried along the frame or rack.

The moving working platform can be retracted at completion of the shift for security from blasting damage.

Another typical approach is illustrated at right, where at Strassa deep hole drilling, with up to 115-ft holes, is used for bench driving. Benches are driven upward along an expanding v-shaped pattern so that broken ore draws down the slanting walls. Not unlike some open stoping and shrinkage approaches, the new approach for this very old iron mine depends on structural conditions, plus drills and machines capable of deep hole drilling.



EXPLORATION

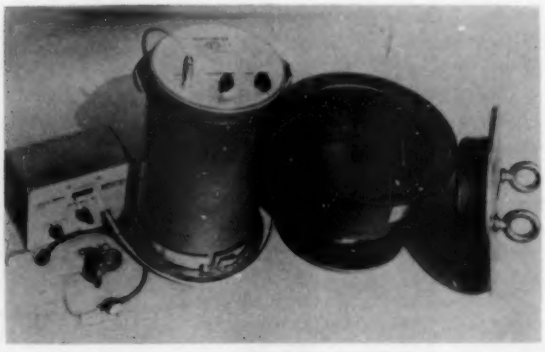
Detailing the steady but complicated progress in exploration is a story occupying books, not pages. But, putting better knowledge to work requires better tools, such as those found on this page. Others might include the miniature seismograph shown on the facing page in an open pit mining application, or the wider use of aerial photography, covered in MINING ENGINEERING *during this and previous years.*

NEW TOOLS

Transporting 34,500 lb of equipment 4 mi to the location of a new exploration shaft in the mountains of Southern Alaska was solved this summer by a helicopter that weighs only 1,700 pounds, empty. A 305 hp Hiller 12 E delivered the cargo in one day, 8 hr, 25 min flying time, saving days of packing to the 4,100 ft site.

The Model 4 Geodimeter, or electronic measuring tape, offers light weight, portability, and low cost to the precision and accuracy of larger models. The new instrument is designed for work in the 50-ft to 3 mile range, and is 12-in. square, and weighs 35 lb.

A second job for this helicopter operated by Livingston Air Service, Corvallis, Ore., under contract to Moneta Porcupine Mines, Ltd., Canada, was to taxi three 2-man prospecting teams along their grids. Each of these 2-man teams, which were sometimes equipped with a 150 lb portable drill, was leapfrogged along the traverses over the 5,000 ft mountainous plateaus. Every team carried exploration equipment and food totaling almost 500 lb in addition to survival gear, pilot, passengers, and more than 20 gals of gasoline.



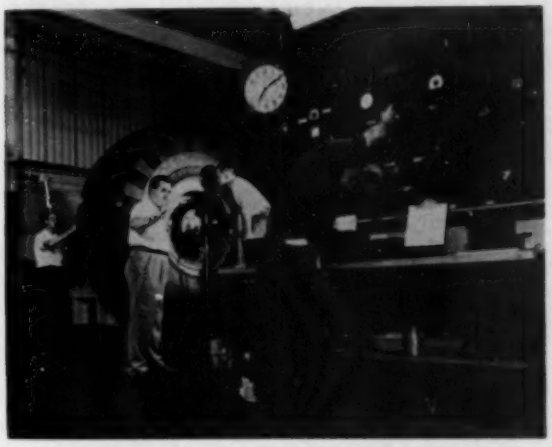
The Berylometer may represent a major breakthrough in the field exploration of beryllium, a metal currently in the headlines for reactor aircraft, missile, and space developments. The portable detector weighs less than 25 lb and can be carried into the field by a two-man team. Antimony 124, which provides the gamma radiation source and has a 60 day half-life, is sealed in a metal capsule (right). When in use, the shield is attached to the lower part of the 5-in. photomultiplier tube (center). For measuring beryllium samples, there is either an impulse counter for quantitative assaying or earphones (both left). The device is manufactured and marketed in the U.S. by Nuclear Corp. of America's Western Div., Burbank, Calif.

OPEN PIT

During 1959 these two new machines or devices appeared as open pit mining techniques moved into a third phase. First, light weight contracting equipment was adapted; second, heavy specially built equipment appeared; now, wholly new designs—specifically originated for earthmoving are becoming more common.

MOTORIZED WHEEL

Twenty years ago General Electric engineers designed an electric wheel drive for Admiral Byrd's Snowcruiser, shown here. This year a new motorized wheel drive for earthmovers in open pit mining and earthmoving contracting has evolved. Shown under test at right above, the GE motorized wheel offers high horsepower utilization throughout vehicle speed range. The drive eliminates transmissions, axles, and gear shifts by including the traction motor as an integral load carrying part of the wheel. All-wheel drive and dynamic breaking are among the other possibilities.



TRAIN ON RUBBER

Latest entry in the field of dump truck haulage is Differential's side dump "Wagon Train on Rubber" made up of a truck with one, two or more trailers. These patented trains are built in two sizes, one for highway use with 15-ton capacity bodies, and a larger off-highway train with bodies carrying 25 tons. The on-highway truck and trailers in the photographs have identical bodies 8 ft wide, with 10 cu yd capacity, and will dump to either side. The driver can dump individual loads without leaving the cab. Cost savings are claimed for: dumping convenience, increased load hauled per driver, higher payload to tare weight.

OPEN PIT

Seismic Analysis Method to Determine Rippability

Not many years ago blasting and shovels was the only practical way to move hard or rocky materials. Development of powerful crawler tractors during recent years has changed this picture, paving the way for application of rippers for shattering and loosening tough materials to speed scraper loading. As experience was gained with this new tool, harder materials were tackled—trying to see if it would work.

Engineers learned that any material could be ripped, if conditions were right. The key to rippability seemed to be consolidation of the material. Caterpillar Tractor Co. engineers tackled this problem, looking for a fast, inexpensive and accurate way to determine if the material could be ripped, before a tractor and ripper was moved in. Now, backed by more than 500 tests throughout the country, the seismic analysis method to determine rippability has been developed.

Seismic analysis offers the desired features. It is simple in theory—sound waves travel through materials of different consolidations at different, predictable velocities. The velocity of the sound or shock wave through the subsurface material provides the answer to: Can it be ripped?

The equipment is lightweight, simple to operate and accurate. It includes a source of the sound or shock wave (an 8-lb sledge will do fine) and a receiver (a standard geophone) and an electronic counter. It all weighs about 40 lb, and can be carried easily by two men.

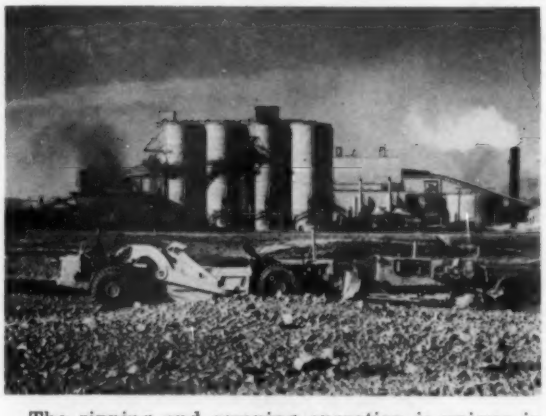
Contractor's personnel can learn to operate this equipment in less than an hour, following directions furnished by the manufacturer, Geophysical Specialties Co., Hopkins, Minn. (The seismograph, including self-contained batteries, costs less than $3,000.) Working with the equipment for a day or two under known conditions will quickly develop reliable accuracy of operation.

Operating procedure is simple. The electronic counter, housed in a small metal container about the size of an overnight case, operates on self-contained batteries. A geophone plugs into one receptacle on the counter's face. A long wire goes into another receptacle and the other end of the wire connects to a spring contact switch on the sledge. A small steel plate, when hit by the sledge, will produce a sufficiently strong wave for readings to 50 ft deep under most soil conditions. Blasting caps wrapped in a couple feet of primacord may be used if stronger waves are needed.

CEMENT PLANT USES RIPPERS

Quarrying limestone by means of ripping and scraping has proven an economical operation at the new 1.4 million bbl Arkansas Cement Corp. plant at Foreman, Ark. During preliminary investigation of the Foreman site, a high-grade deposit of soft limestone chalk was assessed by Kaiser Engineers, designers and builders of the plant. Familiar with the recent economical use of large earth moving equipment, KE recommended that the raw material be mined horinzontally by ripping and scraping.

In Arkansas Cement's operation, the chalk deposit is ripped by two Caterpillar D9 tractors equipped with specially-designed hydraulic rippers. A 33-cubic yard Euclid TS-24 pan scraper is loaded with the aid of one of the D9 tractors and then carries the rock between 1000 and 2000 ft to the receiving hopper. More than 200 tph are delivered to the hopper in this manner.



The ripping and scraping operation is unique in the industry, and eliminates capital costs of a shovel, drilling rig, truck fleet, and other equipment necessary for conventional drilling and blasting.

When the sledge strikes the plate, shock waves are sent through the ground and the switch closes, starting the counter. When the first wave reaches the counter through the geophone, it stops the counter. Time is recorded in milliseconds by flashing lights. The first check is made at 5 or 10 ft from the geophone, and successive checks in a line from the geophone in 5 or 10-ft intervals, depending on soil and job conditions.

A complete test on a cut can be run in less than 30 min. Velocity (V) of the wave is found by the formula.

$$V = \frac{D}{T}$$

where D is the distance from the plate to the geophone and T is the time lapse. This is plotted on a graph, with distance in feet along the bottom and time in milliseconds up the side. Points fall in line for each type of material since velocities are the same for similar consolidations. Intersection of straight lines through adjacent points indicates changes in consolidation.

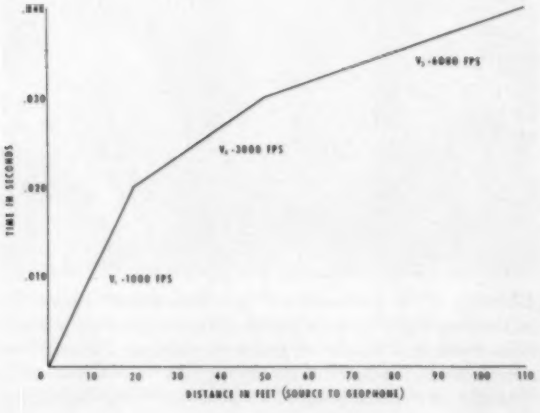
Depth at which these changes occur is computed by the formula

$$D = \frac{X}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

where D is depth, X is the distance along the bottom of the graph from zero to the intersection point of the lines, V_1 is the velocity of the seismic wave in the upper layer and V_2 is the velocity in the next lower layer. Depths of successive layers are determined in similar fashion.

Accuracy has been established by running tests under known conditions and by checking ripper performance after tests. More than 50 contractors own this equipment, using it to determine subsurface conditions before bidding and equipment scheduling. On one highway project in Michigan's upper peninsula and another in the hills of southeastern Kentucky, contractors were planning to drill and blast. Seismic analysis showed large quantities of the rock could be ripped and handled by scrapers, at considerable reduction in cost per yard. Both contractors moved in with mounted rippers, based on these findings.

The large number of tests have been amassed into a set of tables. Rippable and non-rippable velocities

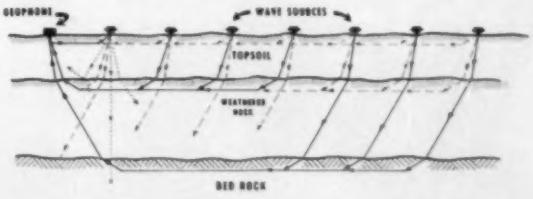


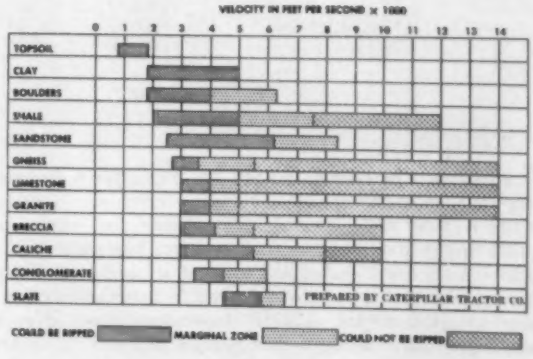
Two-man team operates miniature engineering seismograph to obtain complete subsurface data without drilling. Unit made by Geophysical Specialties Co. has other applications than ripping tests described below.

have been determined for each type of soil. In almost every case, a zone of marginal material divides these two categories. Rippability within this zone depends on soil conditions, machine condition and skill of the operator. Consequently each contractor must determine rippability within this zone. Many times he can almost completely eliminate it through experience.

Satisfactory results cannot be obtained when the surface is frozen. This ground is so consolidated that the surface wave almost always reaches the counter ahead of the subsurface wave, regardless of the density of these lower layers. Likewise, seismic analysis will not reveal the presence of softer materials below harder layers, such as in cap rock areas.

Ripping is not considered a cure-all to every rock-handling problem. A contractor must weigh many considerations in deciding what method to use for a particular case. But seismic analysis is showing the way to lower costs through ripping on many jobs.





ANNUAL REVIEW

Jet Flames Carve Stone

Typical of the fast moving developments in the field of industrial minerals is this latest technique for doing one of the oldest jobs in mining—stone preparation. Pressure, particularly from the booming building industry, has brought consolidations, mechanization, and a new attitude to even the most traditional areas of non-metal production.

The rocket jet principle that generates the tremendous energy needed to power our modern missiles and rockets has been put to another use. Known as Stone-Shaping, this unique process, developed and patented by Linde Co., Div. of Union Carbide Corp., promises to give a terrific boost to the stone-working, building, and construction industries.

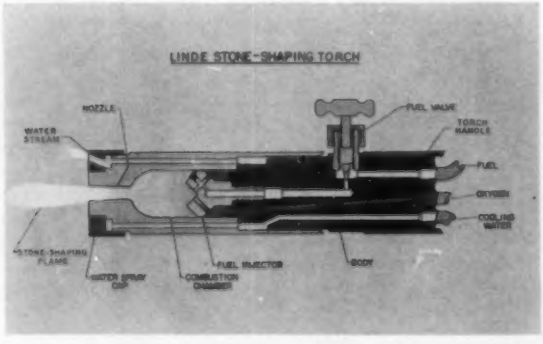
Linde's new process works fastest on the harder stones, such as, granite, quarzite, syenite, sandstone, and taconite, which conventional mechanical methods find toughest and can carve stone five times faster than mechanical methods.

At its highest velocity the small Stone-Shaping flame has a mechanical energy equivalent of more than 25 hp, yet this energy is contained in a flame only 4 in. long. Traveling six times faster than the speed of sound and reaching temperatures of 5550°F, the flame spits out a small manual torch which weighs slightly over 7 lb and is 37 in. long. In addition to its use as a quarry and sculpturing tool Linde's new process is expected to find widespread use in the construction industry.

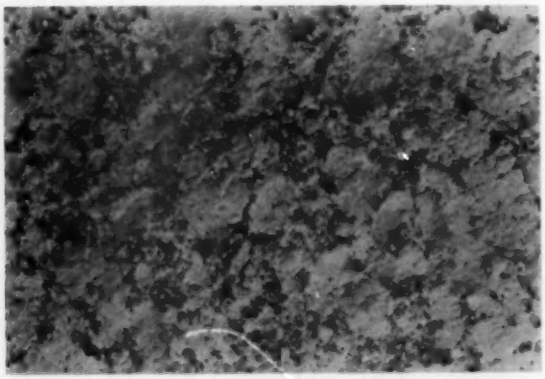
Reduces Cost of Stone: Beside its ability to impart a beautiful finish on granite Linde's process has far reaching economic aspects. The cost of granite facing material, for example, can be cut sharply. It is possible to use Stone-Shaping torches to shape and texture slabs as thin as ⅝ in. The use of 75 pct thinner granite means a 75 pct reduction in the total weight. Reduction of total weight also results in tremendous savings in freight and transportation costs.

Principle of Operation: The Oxweld FSJ-6 Torch burns oxygen and kerosene in an internal, water-cooled, rocket chamber. The resulting flame is emitted from a convergent-divergent nozzle at a velocity of 7000 fps and a temperature of 5500°F. This combination of intense heat and high velocity causes stone to spall. Cooling water for the combustion chamber exits through the front end of the burner and serves a twofold purpose: 1) by positioning the water stream on one side of the spalling path, the stone on that side is protected from the flame and will not spall; 2) the water stream prevents the stone from overheating, eliminating the possibility of thermal cracking. The size of the jet flame is controlled by a fuel control valve on the front end of the torch. A reduction in the fuel ratio produces a smaller and sharper jet flame for more precise stone removal.

Using Linde's new Oxweld FSJ-6 an operator is carving out a one foot deep section of one of the four large granite supporting piers of the Queensborough Bridge in New York City. Each of the four huge piers was cut back 1-ft making it possible to widen the lower deck from five to seven lanes.



Cross-section of Oxweld FSJ-6. The outer torch body is lightweight aluminum. Burner and injector are made of oxygen free high conductivity copper for maximum heat dissipation. Oxygen, fuel and cooling water enter through the back end of the torch. Fuel and oxygen are mixed at injection point and ignited in combustion chamber to produce the 5500°F supersonic flame. No. 1 or 2 diesel oil or kerosene can be used as fuel.



Close-up of a flame-treated granite surface shows the interesting and dramatic visual effects created by Linde's new process. The darker areas of mica and biotite are raised above the spalled areas of feldspar and quartzite. Sunlight at various angles creates sparkling highlights.

A Long Range Appraisal of Mechanical Mining

A. LEE BARRETT IS DIRECTOR, RESEARCH AND DEVELOPMENT, JOY MANUFACTURING CO., PITTSBURGH, PA.

Any realistic appraisal of the future of mechanical mining must include the mining system as a whole, as well as the machinery for the system. History, which usually bears some relationship to the future, seems to indicate in the case of coal mining, that a significant portion of cost reduction resulting from the introduction of new mining machinery comes from a change of methods or mining plans made possible by the use of new machinery.

While the figures with respect to performance and cost vary widely between mines as a result of the proximity of the market, quality of coal, etc., certain limitations can be reasonably established with respect to mine performance. The figures shown in this report are made to be representative of a general situation, and should not be referred to any specific mine operation. These figures have been compiled by averaging certain mine performances in order to illustrate the relationship of the various factors in mining.

THE PAST

In the 1920's when coal was primarily loaded by hand, miners usually produced 4 to 6 tons per man at the face. If, as normally practiced, the place was worked 1 shift by 1 man, a 5,000 ton mine required 1,000 coal loaders and 1,000 mine working places. Distribution of mine labor averaged 70 pct face men and 30 pct non-face men; therefore, in a 5,000 ton mine approximately 300 men worked on construction and maintenance of track, ventilation, haulage, drainage, coal preparation, etc. With the passage of the hand loading era came the period dominated by off-track mechanical loading.

Tonnage per face man in the off-track mechanical era (1930 to 1952) generally ranged between 15 and 45 tons. A 12 man crew averaging 33 tons per man produced 400 tons a shift. This method of mining required 7 double shift working sections to produce 5,000 tons. Assuming each working section had an average of 7 working places, a 5,000 ton mine employed 84 men to work 49 places. A representative distribution of labor for this area might be 60 pct face labor and 40 pct non-face labor—including coal preparation.

The introduction of continuous mining from 1948 once again made a change in the distribution of cost and labor. Using this process it is normal to expect between 30 and 100 tons per face man. A 5 man face crew averaging 50 tons per man produces a total of 250 tons a shift. Thus, 10 double shift working sections produces 5,000 tons per day. Each working section now generally represents one place, so that ten working places are required for the production of the mine. Distribution of labor using this system is approximately 50/50—50 face men and 50 non-face men for a total of 100 men in the mine. Note particularly that with these assumed figures, the mine is greatly reduced in area as a result of our progress in mechanization. The ratio of working places between the hand and off-track mechanical mine is approximately 20:1. The ratio of working places between the off-track mechanical mine and the continuous miner mine is 5:1. Thus, the ratio between the off-track hand loading mine and the continuous miner mine is 100:1. These figures represent possible shrinkage in the working area of a mine. Thus a great portion of the reduction in mine cost which has occurred within the past 40 years has resulted from the shrinkage of mine area.

THE PRESENT

On the basis of a common labor cost of $25.00 per day, face labor at the hand loading area would cost $5.00 per ton, in the off-track mechanical loading 76¢ per ton, and in the continuous miner area 50¢ per ton. In the case of the hand loaded coal the $5.00 represented by far the major cost of the coal produced. In the case of the mechanical loaded coal, however, a number of new factors have been added to the cost including, principally, maintenance cost and amortization. Many of the non-productive costs (other than face costs) have specific relation to the area of the mine. For instance, a transportation system spread over a wide area will cost more to install, operate and maintain. Similar cost effects in the mine are present in the drainage system, roof control, ventilation, safety program and supply handling, as well as in the capital cost of developing the mine. The listing in the table on p. 152 represents an attempt to evaluate the area affect on each item in these costs.

It is difficult to obtain a complete and accurate evaluation of these various relationships for any particular mine; however, adding the increments together, dividing by twenty to include items which do not vary with the mine area, results in an average cost effect of approximately 29 pct. This factor was applied to an average total cost of $1.40 for transportation, ventilation, drainage, roof control, rock dust, supply handling, capital, etc. as determined at five mines, and represents 32¢ per ton.

To illustrate by formula:

(Reduction in area) × (area cost effect) × (cost of elements) = Saving); or, $(1-1/5) \times .29 \times \$1.40 = \$0.32$

This 32¢ per ton presumably represents the savings that can be made in a continuous miner mine as compared to an off-track mechanical mine if the mine overall working area is reduced in proportion to the number of working places required. This is a large

number in relation to other possible cost savings available today and should not be neglected. The coal mining industry must find ways and means to operate continuous miners in close proximity and thus take advantage of this saving. A great deal of ingenuity and planning will no doubt be required as a result of the general congestion. Traffic control in particular will be a real problem. Improved control of roof will be required in order that places and extraction areas may be maintained in proper relation to one another. Adequate power supply will present a problem as large amounts of power will be needed in a concentrated area which will move rapidly. There will be a tendency for production to be more variable as a result of variation in mining conditions and storage facilities may be required at the mine in order to handle shipping requirements. More variations will be noticed in daily and weekly costs, perhaps spreading over an even longer period. It must be remembered, however, that the cost at the end of the year will be the important factor and the short time variations will have to be taken in stride.

The circumstances and problems surrounding the high concentration of continuous mining machinery require that mining plans be developed to fit the mining machinery. A higher cost can certainly be expected if the new mining machinery is operated in the old mining system.

Certainly transportation is one of the big problems, and mining plans providing a minimum of corners in the transportation system will be needed. The block system for instance, while generally accepted as a good system so far as roof control is concerned, is a poor arrangement when maximum transportation potential is considered. Most continuous miners today are severely handicapped productionwise by a lack of transportation.

THE FUTURE

When considering mining machinery in the long range plan it is important to remember that face labor has already been reduced to some 12 to 30 pct of the mine cost. This is a long step when compared to hand loading and it means that other cost factors must be given more consideration in the future. Certain costs such as taxes, coal royalties or the cost of coal, and the welfare fund are relatively fixed; however, maintenance cost (both labor and material) and amortization are two items which the manufacturer and operator must give serious consideration. It is felt that manufacturers must consider and consolidate the facts which have been developed in our continuous miner experience today, and together with the operator, must produce an integrated system of mining. An example of the results possible from this kind of approach is illustrated by the production of the B58 Hustler bomber. This is the first bomber produced as a weapons system. Previous bombers were sold by aircraft manufacturers afterwhich engines, guidance systems, control equipment and weapons were purchased item by item from various manufacturers. With the advent of the B58, each item going into the bomber was considered as an integral part of the final machine to be delivered. The final result of this philosophy was a bomber so much faster than previous bombers (approximately two times the speed of sound) that its actual performance has not been released to this day.

In the case of mining, such factors as ventilation and transportation must be integrated in the solution of the problem. The Joy-Union Carbide Miner is an example of such a broad front attack. This machine, which is being developed in association with Peabody Coal Co., while probably a larger first step than will be taken underground, is a step which coordinates all aspects of punch mining, transportation, roof support, power supply, etc. Estimates for this proposed setup have been made which show face costs ranging from 5¢ to 30¢ per ton, and overall costs ranging from $2.06 to $3.00 per ton. These variations depend on choice of operating crew (two to six men per shift), and on assuming a shift tonnage ranging from 600 to 1400 tons. A 200-day year is used. The actual cost will probably be near the lower figures. It will be noted from these figures that face labor is at a minimum and that cost control will depend on control of factors other than labor.

All enterprise tends to operate on certain plateaus of performance. For instance, the electric light industry operated for a long time with filament electric light bulbs. A giant step was made when the fluorescent light was introduced. The aircraft industry had one plateau in the reciprocating engine area, has entered another with the jet engine, and faces a future plateau in the ballistic age. The home washing machine industry had a plateau with the washboard and tub, another with the mechanical washer, and today is operating in the automatic machine field. These examples show that while significant gains can be made within a plateau, the establishment of a new plateau results in a giant step for the industry.

In coal mining our plateaus have been hand mining and off-track mechanical mining. We are now approaching a new plateau which will be integrated continuous mining. This will represent another giant step for the industry.

NON-PRODUCTIVE FACTORS AFFECTED BY MINE OPERATING AREA

ITEM	EFFECT OF AREA REDUCTION
TRANSPORTATION	
Construction	30
Operation	20
Maintenance	60
VENTILATION	
Construction	30
Maintenance	70
DRAINAGE	
Construction	50
Operation	50
Maintenance	70
ROOF CONTROL	
Construction	40
Maintenance	50
ROCK DUST	
Initial	0
Maintenance	50
Supply Handling	40
CAPITAL	
Equipment	−5
Mine	25
Mics. (Weight 5)	None

WATER LAWS RELATED TO MINING

by WELLS A. HUTCHINS

Water laws important to the mining industry are those which govern or affect the right to use water, to dispose of water after using it in mining or milling, and to discharge waste material into watercourses. They include statutes and court decisions having general applicability, as well as others that pertain specifically to mining.

THE INDUSTRY'S CONTRIBUTION TO WESTERN WATER LAW

Despite sharp differences of opinion, the water law the Spaniards brought to the Southwest appears to have included some form of appropriation of water. The Mormons, who settled in Utah in the mid-nineteenth century, also developed a system of appropriative water titles. But by far the most profound impact on western water law was made by the gold-seekers who flocked to the Sierra Nevada foothills of California after the discovery of gold in 1848. Much of the gold was extracted from the ground by hydraulic or placer mining, and so the miners' rights to the use of water became fundamentally important. Since there was no organized government in the foothills and no laws other than those made by the miners, they helped themselves to the land, the gold, and the water needed to work their claims.[1] They established and enforced regulations governing the acquirement and holding of mining claims and their rights to the water they needed.[2] In 1879 Justice Field, former Chief Justice of the California Supreme Court, spoke for the U. S. Supreme Court in saying that the miners were "emphatically the law-makers, as respects mining, upon the public lands in the State."[3]

Rules of the California mining camps were based on two essential principles: 1) priority in discovering claims and appropriating water by diverting it from streams and putting it to use, and 2) diligence in working claims and applying water in mining. The customs so developed, which were copied in mining areas of other states and territories, were enacted into law in one western jurisdiction after another. They form the basis of what is called the arid-region doctrine of prior appropriation of water, which received the attention of Congress in legislation recognizing and protecting appropriations of water for mining, agriculture, and other purposes on the public domain.[4] In several western states a great number of water cases decided in the early years involved relative rights to the use of water for mining purposes or for milling connected with mining.[5] The miner's inch, the customary unit for measuring water in the mining camps, is still used in various western communities, although its relation to the cubic foot per second varies from one area to another. Undoubtedly, the miners of a century ago made the major contribution to the appropriation doctrine as it is now recognized and applied throughout the West.

What inspired the California gold-seekers to develop these principles? Thoughtful writers have pointed out that their regulations and customs were strikingly characteristic of much earlier mining enterprises in the Old World.[6] It is said that the right of free mining and free use of flowing water therefor—so similar to the California conditions and practices—was a part of the customs of Germanic miners in the Middle Ages, that it spread from middle Europe to other countries and colonies, and that the doctrine of prior appropriation was widespread in the important mining regions of the world. Certainly the Forty-niners came to California from many countries. It does not tax the imagination to consider that they may have brought with them some knowledge of the old Germanic customs and applied this knowledge in their new environment.

RIGHTS TO USE OF WATER IN GENERAL

In the West, rights to the use of water of watercourses fall into two categories—appropriative and riparian. The doctrine of prior appropriation is recognized in each of the 17 western states. The riparian doctrine is recognized concurrently with the appropriation doctrine in some of these states but has been abrogated in the others. The riparian doctrine prevails generally throughout the East, although there is now considerable interest in developing something else. Generally speaking, the appropriation doctrine has been highly developed in the West, whereas the principles of riparian doctrine have been comprehensively established in only a few states throughout the country.

The subject of water rights is a big one. Space permits no more than a brief discussion of aspects that bear upon the title of this article.

RIGHTS OF PRIOR APPROPRIATION

Fundamental to the doctrine of prior appropriation is the principle *first in time, first in right*. Although in some states there are statutory exceptions, the original and still generally prevailing rule is that the first one who initiates a right to divert and use water of a stream, and who completes his undertaking with reasonable diligence, acquires thereby the first right of appropriation of the specific quantity of water involved. Each succeeding right in point of time is junior to all earlier rights but senior to all later ones. The practical effect of this priority system is that when the water supply is not enough for all, the earliest rights must be fully satisfied before any water may be taken by those later in time.

Acquirement of Appropriative Rights: Each of the 17 western states has a statute under which water may be appropriated pursuant to a prescribed procedure. Generally, the first step to be taken by the intending appropriator is to file application in the office of the State Engineer for a permit to make the appropriation. In most but not all states, valid ap-

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propriations of water may be made only by following this procedure.*

* For two exceptions, see Ref. 7.

Place of Use: Under the appropriation doctrine, water may be used on land regardless of its contiguity to the stream from which the water is diverted. In most states it may be used, under certain conditions, in a watershed other than that in which it originates.

Loss of Water Rights: The appropriative right remains in effect so long as it is properly exercised. But if the holder ceases to make beneficial use of the water the right is subject to loss. This may occur in several ways: voluntary abandonment by the holder; failure to use the water throughout a period of years prescribed by statute; prescription on the part of an upstream claimant; or equitable estoppel.

RIPARIAN RIGHTS

The riparian doctrine accords to the owner of land contiguous to a watercourse the right to use the water on or in connection with his riparian land, solely by reason of its location. The riparian owner's water right does not relate to a fixed quantity of water, as does the appropriative right. In general, it encompasses such quantity as is reasonable at a particular time in consideration of the reasonable needs of other riparian landowners—a highly variable factor. In the strict exercise of the riparian right, the place of use of the water is confined to the land to which the right relates. Under some circumstances, however—particularly when no injury results to other riparian landowners—courts in some states have sanctioned use of the water on other riparian land and even on nonriparian land.*

* Both cases referred to in Ref. 8 involved the obtaining of water supplies for oil drilling operations.

The riparian right is a part of the riparian land itself, and it is acquired with acquisition of title to the land. The right may be lost by prescription, and there are other ways in which it can be separated from the land.[9]

RIGHTS TO USE OF GROUND WATER

Several systems of water rights apply to those sources—known as ground waters—that exist naturally under the surface of the earth. If such waters move through the ground in definite streams, the law of water courses governs their use. Otherwise the ground waters are called *percolating* and are subject to rights of use that vary from one jurisdiction to another. That is, in some states the owner of land owns the percolating waters that exist in his land; in others he has rights of reasonable use somewhat comparable to the riparian right; and in still others the appropriation doctrine applies.[10]

SOME ASPECTS OF WATER RIGHTS

Purpose of Use: Appropriative and riparian rights and probably most ground water rights contemplate the use of water for reasonable beneficial purposes without unnecessary waste.

Mining is a use of water for which an appropriation can be made; in fact, as above stated, it was for mining purposes that the gold-seekers developed a system of appropriative water rights in the Sierra foothills a century ago. And during that development period the California courts likewise applied the riparian principle to mining water rights. The lands belonged to the Government, which was not asserting its water rights, but the courts held that the possessors of claims—who were technically trespassers—nevertheless acquired water rights that were good as against each other. Thus, those whose mining claims were not contiguous to streams became appropriators, whereas the possessors of contiguous claims were considered as having rights analogous to riparian rights of actual landowners.[11]

Preferences in Use of Water: In both the appropriative and riparian water law philosophies of the West, there are preferred uses of water. Those that pertain to appropriations are prescribed by statute, whereas riparian preferences are declared by the courts, which indeed created the riparian doctrine itself. In either case, use of water for sustaining human life—commonly called *domestic use*—stands above all others.

Appropriative Preferences: Whenever these preferences are declared, the statute or constitutional provision, as the case may be, lists domestic use as first, and in most cases agriculture as second. The long Texas list departs from the usual in that, while first place goes to domestic and municipal uses, the second is "Water to be used in processes designed to convert materials of a lower order of value into forms having greater usability and commercial value, etc," third is irrigation, and fourth is "Mining and recovery of minerals."[12] The constitution of Idaho places domestic use above all others and agriculture above manufacturing, but goes on to provide that in any organized mining district those using the water for mining or for milling purposes connected with mining shall have preference over manufacturing or agricultural uses.[13]

Just what does a preference imply? Chiefly one of two things: 1) If two or more conflicting applications to appropriate water are pending before the State Engineer, he must approve the application for the higher use, whether or not it was filed first. In some cases he may even have authority to defer action on an application pending a prospective filing for a higher use. 2) An organization or agency possessed of the power of eminent domain may condemn an existing water right in order that the water may be put to a higher use. This does not mean that a vested appropriative right may be extinguished so that the water may be put to a higher use by some other holder without the payment of just compensation, unless in its acquisition the earlier right was expressly conditioned upon such a hazard.* In fact, the

* In Texas certain appropriations are conditioned on their possible subordination to later appropriations for domestic and municipal purposes without compensation. See Ref. 14.

Idaho constitutional provision above noted declares that exercise of the preferences shall be subject to the condemnation statutes.

The Texas water appropriation statute contains another preference that relates specifically to mining,[15] to the effect that when an application is made to appropriate water from a stream for mining purposes, the owner of the land through which the stream flows shall have the prior right to appropriate the water—regardless of whether he has theretofore filed—provided he files his preferred application within 10 days after notice of the other party's application.

Riparian Preferences: Under the riparian doctrine the use of water for domestic purposes is an ordinary or natural use entitling it to preference over agricultural and industrial purposes. This means that to sustain the life of his family the riparian owner may use as much water as necessary, but for farming or

other business purposes his needs must be coordinated with those of all other riparians.[16]

Changes in Exercise of Water Rights: Another point of water law that requires emphasis in this discussion is that in most states the holder of an appropriative right may change the point of his diversion of water, or the place or purpose of use, provided that in doing so he does not impair the rights of others. Such an injury may result, for example, if an appropriator for power purposes—a nonconsumptive use—endeavors to change his right to irrigation of farmland. Again, a change of place of use to distant locality could, under some circumstances, seriously affect a downstream community that has been depending on the return flow from the upper project.[17] The right to make changes not harmful to others was established in the early courts. Various old mining ditches in the Sierra foothills of California are now used for power and irrigation projects.

Holders of riparian or overlying ground water rights may change their points of diversion from one place to another on their land and may change from one purpose of use to another. Whether they may change the place of use to other land depends on the jurisdiction.

WATER RIGHTS FOR MINING PURPOSES

With these observations as a background, it is time now to turn to some of the ways in which water has been and is used in the mining industry.

Hard Minerals: The washing away of hillsides, which was carried on so lavishly in the course of early hydraulic mining in California, resulted in the accumulation of so much debris in the river channels below that Congress took action to protect the navigability of the Sacramento and San Joaquin rivers.[18] Operations in the watersheds of these streams were subjected to public regulation through the California Debris Commission. Large quantities of water were used in these early operations.

Water rights pertain to the water used in exploration and drilling operations, in running machinery, and in processing minerals. Water is needed for allaying dust both underground and on the surface, for diamond drilling, and for whatever milling operations are undertaken. The quantities required for drilling are comparatively small. Milling requirements may be considerable, and if the water supply is not plentiful, efforts may be made to recover part of the water by using settling ponds or by other means.

The uses of water in exploration and in extracting minerals are mining purposes. Whether the processing uses are to be classified as mining or industrial may depend upon the particular state policy.

In addition to these mining and milling uses there is water consumption in the associated mining community, which is so closely related to the mine itself that if operations close down the community may become a ghost town. Consumption of water for this essentially domestic use may be considerable.

Petroleum: In the petroleum industry water rights are required with respect to uses of water in drilling, recovery, and refining operations.

In exploratory drilling by the rotary method,[19] in which drilling mud is pumped down the hollow drill pipe for the purpose of cooling the cutting edges of the bits, the use of water is a reasonable beneficial use.*

* This is clearly implied in the Texas cases cited on page and in Ref. 8. See also Ref. 20.

In secondary recovery water-drive operations water is needed to flood oil reservoirs in which extractions have reduced the initial gas pressure to a low level. As the natural pressure subsides, water is forced down injection wells and out into the oil-bearing strata in order to rebuild the pressure at withdrawal wells and thus increase the percentage of recoverable oil.*

* See Ref. 21. Williams et al. raise a question as to whether a landowner or lessee may exercise recycling or secondary recovery operations the effect of which extends to the part of the structure underlying the lands of another. They cite Tidewater Associated Oil Co. vs Stott, 159 Fed. (2d) 174 (5th Cir., 1946; certiorari denied, Stott vs Tidewater Associated Oil Co., 331 U. S. 817, 1947), which involved the injection of dry gas into the structure, as having apparently recognized this "negative right," at least inferentially.

In some areas concern has been expressed as to the validity of appropriations of water for secondary recovery operations. Where nonpotable water, such as salt-impregnated water available in the oil fields, is used in these water-injection programs, there is at least no competition for water of the quality required for domestic and agricultural uses. The competitors probably are chiefly or solely owners of lands overlying ground water reservoirs, or claimants of rights in stream waters, who wish to use the water in oil fields, in which case relative rights for the same use of water, rather than reasonableness of the purpose of use, would be expected to be at issue in a legal controversy. However, although no decisions of appellate courts on this point have come to the author's attention, it is his belief that the use of even potable water for these flooding operations does not conflict with concepts of reasonable beneficial use that have been declared by the western courts. Where this use of water would fit into a statutory list of preferential rights in a particular jurisdiction probably remains to be determined. The writer knows of no precedents.

Right to Use of Return Flow from Mining Operations: The portion of water which is diverted from a stream in excess of the quantity consumed and which returns to this stream or finds its way into another water supply is called *return flow*. The right of an appropriator to recapture and re-use this excess quantity before it escapes from his premises has been acknowledged in various cases, but the rules as to whether he can recapture the water after it so escapes—and if so, where the recapture can be legally effected—vary from one jurisdiction to another.[22] With important qualifications, waste water that has been abandoned by the original appropriators may be again appropriated in certain jurisdictions, particularly if it has not yet re-entered the stream from which it was diverted, but in the usual case the original user is not obliged to continue the waste.[23, 24]

One of the important return-flow cases in Montana involved the classification of water diverted from watershed *A* into watershed *B* for placer-mining operations and thereafter released into a stream in watershed *B*. The Montana Supreme Court held that on the relinquishment of this return water into watershed *B* it became a part of that watershed and not a part of the water to which rights of use in watershed *A* attached.[24]

The Colorado courts, in a series of cases, have taken the extreme view that once appropriated water escapes from the land or waterworks of the appropriator and starts on its way back to the stream from which diverted, it becomes a part of that stream as completely as though it had never been diverted from it.[25, 26] Elsewhere there are not so many judicial

precedents, and some cases allowing recapture have been decided.[85, 86]

An early Colorado statute provides that waters raised from mines in the course of mining or milling, and thereafter reaching a natural channel away from the premises, are beyond the control of those who raise them and subject to taking by others.[87] The Colorado Supreme Court held that one who conducted such water into a stream by agreement with the mine owners and there appropriated it was the prior appropriator.[88]

Acquisition and Exercise of Mining Water Rights Summarized: Rights to the use of water for mining and processing hard minerals and oil may be acquired by appropriation, or by reason of ownership of land riparian to streams or overlying ground water supplies, depending on the local situation and on the particular jurisdiction in which the question arises. Mining is a reasonable beneficial use of water and in the writer's opinion, until the courts hold otherwise, this applies to its use in secondary oil recovery or recycling operations. Where preferences in the use of water are applied, mining is invariably superseded by domestic use; otherwise its place in the preferential order depends on the jurisdiction. The principles governing changes in point of diversion, place of use, and purpose of use, the necessity of beneficial use without unnecessary waste, rights to the use of return flow, and the loss of water rights apply to mining uses as well as to other uses of water.

SOME LEGAL PROBLEMS IN DISPOSAL OF WASTE WATER AND OTHER MATERIALS

The legality of the methods of disposal of excess water after its use in mining and milling operations, and of disposal of waste materials into watercourses, are in different categories of water law from that relating to rights to the use of water.

The legality of the discharge of excess water into a public drainageway would depend upon conformance to the drainage laws of the jurisdiction, and to any other statute or administrative regulation that governs such activity, and upon absence of resulting injury to others.

Quality of the water and effect on capacity of the drainage channel are important factors. Additions of good return flow to a natural water supply are not only welcomed by the water users, but have also been the subject of numerous controversies over rights of use.[88, 89] Complaints over the disposal of waste water and other materials deal chiefly with the discharge of debris, contaminated materials, and polluted water into streams on which water rights are claimed and which have other public values.

Character of Resulting Injuries: Dumping of gravel and soil into a stream channel to such an extent as to fill up the bed, and deposition of polluted mining debris or water in the stream, may cause injuries of different character and may have different legal effects. Thus, the results of dumping material into the channel may cause the stream to overflow and flood or erode adjacent lands; it may interfere with existing diversions from the stream; or it may even impair its navigability. It was on this last-named ground that Congress took action with respect to hydraulic mining in the watersheds of the Sacramento and San Joaquin valleys in California.[10] The operations may cause injury to individuals only, and so be at issue in private controversies and litigation, or they may affect the public adversely and hence become public nuisances. Likewise, the discharge of injurious substances or impregnated water into natural water supplies may cause either private or public injuries. And so there have been, on the one hand, many private suits for damages and injunctions against operators of mining, milling, and oil properties, and on the other hand, enactment of statutes and promulgation of administrative regulations invoking the police power of the sovereign in the interest of the public welfare.

As with the law of water rights, discussion of this considerable field of water law in this paper must be confined chiefly to a few generalities and illustrations.

Injuries to Private Property—Mining Operations: In a very early case, the California Supreme Court took the position that: 1) it would be unrealistic to hold that a downstream appropriator in a mining region is entitled to water in as pure a condition as when he first constructed his ditch and 2) as to deterioration in quality as the result of upstream mining operations, "the injury should be considered as an injury without consequent damage."[37] This extreme view was later repudiated by the court[38] in favor of the principle that the appropriator is entitled to protection against acts that *materially* deteriorate the quality of the water for the uses to which he originally devoted it.[39]

Early in the present century the Arizona Supreme Court held that an agriculturist might not captiously complain of the reasonable use of water by a miner upstream, even though it polluted and rendered the water somewhat less desirable, but that he was not required to submit to such pollution or accumulation of debris as to impair his water right substantially.[90] In affirming this decision, the U.S. Supreme Court announced the principle that as between water users, the lower of which complained of pollution of the water by upstream mining, the question of deterioration of quality and of resulting injury were matters of fact, to be determined independently in each case. The Court stated:[91]

> The Arizona statute places a water user for mining purposes upon no higher plane than a user for irrigation. The suggestion that the right to use for mining and reduction purposes cannot be exercised without polluting the streams with waste material, tailings, etc., and that the lower user cannot, therefore, complain of the necessary consequences of the legal right conferred by statute, is without force. The only subordination of one water user to another is the right of the first appropriator to uses. That includes the quality as well as the quantity. What diminution of the quality of the water will constitute an invasion of the rights of the lower appropriator will depend upon the facts and circumstances of each case, with reference to the use to which the water is applied.•••

In 1939, the Idaho Supreme Court expressed its approval of the statement of the Arizona Supreme Court, and stated:[92]

> Numerous authorities announce the doctrine that while a prior use of the water of a stream for mining purposes necessarily contaminates it to some extent, such contamination or deterioration of the quality of the water cannot be carried to such a degree as to inflict substantial injury upon another user of the waters of said stream.•••

In a much earlier Idaho case, the supreme court had held that the constitutional provision according preferences in favor of mining purposes or milling purposes connected with mining in any organized mining district[93] did not authorize parties engaged in

mining or any other occupation to fill up the natural channel of any public stream to the injury of other water users."[24] And with reference to a contention that this provision authorizes miners to discharge poisonous mineral matter into a stream without liability for injuries to downstream farms, a Federal court said later that this contention "asserts for the miner in Idaho constitutional rights unknown to American constitutional law" and is wholly unwarranted."[25]

Injuries to Private Property—Petroleum Operations: Much litigation has occurred with respect to asserted injuries to property and pollution of water supplies resulting from the escape of waste water and oil in the operation of oil properties. In these cases questions of nuisance, negligence, or breach of a statutory duty have been involved."[26]

A few examples of claimed pollution of streams may be noted. Early in the present century the Texas Court of Civil Appeals held it to be well settled that the wrongful pollution of a stream by one riparian owner—in this instance, an oil company—to the injury of others would entitle the injured parties to an injunction and damages."[27] It would be no defense to such a suit, said the court, to show that the pollution was a natural consequence of conducting a lawful business and was not caused by negligence. In another case, which did not involve oil properties, the same court pointed out that: 1) in the use of a stream, of a kind generally recognized by the public and the courts as legal, a slight impairment of the quality of the water, necessarily incident to the use when carefully and properly regulated, cannot be deemed unreasonable and an invasion of the rights of others and 2) whether a legal right of a riparian owner has been invaded by the use another riparian owner makes of the water is a question of fact, depending upon whether the latter's use is reasonable."[28] And in Oklahoma, in answer to the contention of a riparian owner that an oil company was discharging into the stream large quantities of drilling mud, base sediment, etc., which resulted in damage to his land, the supreme court held in 1940 that the mere act of pumping excess drilling water into the stream was not of itself unlawful and that it was not to be deemed unreasonable unless it was the proximate cause of injury to the lands or rights of others."[29]

In addition to excess drilling water, there is the problem of disposing of water brought to the surface in the operation of oil wells, and separated from the oil thereafter, in such manner as not to impair the rights of others. Also, in making injections of salt-impregnated water in connection with recycling or secondary recovery operations, it may become necessary in some places to avoid harmful contamination of fresh ground water supplies to which private rights of use attach or to which anti-pollution statutes may relate.

Public Regulation: "A river is more than an amenity," said Justice Oliver Wendell Holmes, "it is a treasure."[30] In various states, statutes have been enacted with respect to the disposal of sewage, mining or other industrial waste, or other activities that may result in the contamination of natural streams and other public waters. They were passed, not for the settlement of private disputes, but for the preservation of these natural treasures for the useful purposes to which their waters may be put, and in the interest of public sanitation. In addition there are statutes designed to protect ground water supplies from contamination caused by defective wells.

A fairly recent example of a statute that not only prohibits the pollution of surface and ground waters, but also provides workable machinery for enforcement, is the California Water Pollution Act."[31] The State Water Pollution Control Board includes the heads of state agencies directly concerned with the subject and also members appointed from interested fields. The state board formulates statewide policies and deals with regional water pollution control boards of nine regions into which the state is divided. Each regional board prescribes requirements relative to any particular condition of pollution or nuisance, existing or threatened, in the region. The regional board may hold hearings and make findings, corrective measures being taken in court proceedings brought by the district attorney.

Legal Problems in the Disposal of Waste Summarized: Injurious practices in disposing of excess water and waste materials in hard mineral and petroleum operations may affect the property of individuals, and so be the subject of private lawsuits, or may have such bearing upon the public welfare as to call for public regulatory measures. As a general rule in litigation between individuals, the complainant has redress by way of damages or injunction, or both, only if he can prove actual injury, and in what is probably the usual case, to invoke the judicial remedy, the injury must be material and substantial. The public interest in control of pollution of natural stream channels goes beyond the question of injuries to individual property holders. It extends both to the preservation of natural streamways and other sources of water supply for all the beneficial purposes to which these resources may be put, and also to the prevention of unsanitary conditions. Methods of disposal of waste from mining operations, therefore, must be such as to avoid both substantial injury to private property and also conflicts with public regulatory measures.

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CYANIDE LEACHING TO EXTRACT COPPER FROM ZINC CONCENTRATE

by NORMAN HEDLEY and HOWARD TABACHNICK

The extraction of gold and silver from ores with alkaline cyanide solutions is well known. Cyanide solutions are also good solvents for many base metal minerals, particularly most of the copper minerals. Leaver and Woolf,[1] who determined the solubilities of copper minerals in 0.10 pct sodium cyanide solution, showed that malachite, cuprite, chalcocite, and bornite are readily soluble in cyanide; least soluble are chalcopyrite and chrysocolla.

The Mining Chemicals Laboratory of American Cyanamid Co. has studied the possibilities of using cyanide solutions for leaching base metals. In this article the authors present the results of their experiments with cyanide leaching to reduce the copper content of a zinc concentrate from 0.050 pct to the desired specification of less than 0.02 pct.

Zinc Ore Sample: The sample of commercial zinc ore used in this investigation to produce zinc concentrates was ball mill feed ranging from ½ in. to fines. The ore was crushed to −10 mesh and riffled into 600-g charges for zinc flotation. Analysis revealed 4.54 pct Zn and 0.005 pct Cu.

Examined microscopically, the ore consisted essentially of cream-colored sphalerite and carbonate gangue. It contained a small amount of pyrite, partly tarnished. The only copper mineral identified was chalcopyrite, mostly smaller than 20μ, some of which occurred as attachments on sphalerite.

Flotation Procedure: Batches of zinc concentrates were made as required according to the following general procedure. A 600-g charge of −10 mesh ore was ground for 4 min at 60 pct solids in a laboratory steel rod mill. Screen sizing showed it to be all −35 mesh with 42 pct −200 mesh.

The pulp was transferred to a Fagergren laboratory flotation machine, diluted to 25 pct solids and conditioned for 5 min with 0.6 lb per ton $CuSO_4 \cdot 5H_2O$. It was then conditioned with 0.10 lb per ton Sodium Aerofloat promoter and floated for 5 min with pine oil as frother and creosote as froth stiffener. The pH during flotation was 8.5. A typical analysis of zinc concentrate subjected to leaching is 44.41 pct Zn and 0.051 pct Cu. The ratio of concentration was close to 10 to 1.

Leaching Procedure: Aero Brand cyanide, technical calcium cyanide analyzing 49.5 pct NaCN equivalent, was used for all cyanide leaching tests. For each test three rougher concentrates floated as described were combined (total weight close to 180 g) and the water content adjusted to 150 ml. The percent solids in the pulp was thus 55. After a weighed amount of cyanide flakes had been added, the pulp was agitated on rolls for a given period, then filtered and washed. Filtrate and washed concentrate were assayed for copper content.

The procedure for ammonia leaching was similar to the cyanide process. A series of tests was run in which the effects of ammonia as a solvent for copper in the zinc rougher concentrate were investigated. In each test 180 g of zinc rougher concentrate was leached with 150 ml of ammonia solution. Various strengths of ammonia and times of leaching were investigated. The results are shown in Table I.

It is apparent that ammonia was a poor solvent for copper in the zinc concentrate; 60 min of agitation with a relatively strong NH_3 solution extracted only 2 pct of the copper.

CYANIDE LEACHING TESTS

Effect of Solution Strength: The solvent effects of 0.125, 0.187, and 0.250 pct NaCN equivalent solutions were compared for leaching periods of 15 min. Residue and filtrate were assayed for copper content. The copper content of the filtrate plus wash was calculated back to the original volume of cyanide solution (150 ml).

The effects of cyanide strength are given in Table II. It will be noted that 15 min leaching with 0.25 pct NaCN equivalent solution extracted 74.6 pct of the copper in the zinc concentrate. The leached product assayed 0.013 pct Cu, appreciably below the required specification of 0.020 pct.

Effect of Leaching Time: Portions of zinc concentrate were leached with 0.25 pct NaCN equivalent

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solution for various time periods. The amount of cyanide in each solution was equivalent to 4.17 lb NaCN per ton of zinc concentrate treated. From the results shown in Table III it is apparent that a leaching time of 10 to 15 min with 0.25 pct NaCN equivalent solution is adequate to bring the copper content of the zinc concentrate down to the desired specification of less than 0.02 pct.

Table I. Leaching with Ammonia

Test No.	NH_3 Added, Lb Per Ton of Conc.	NH_3 in Leach Solution, Pct	Leaching Time, Min	Cu in Residue, Pct	Cu Extracted, Pct
1	10	0.6	8	0.049	2.0
2	25	1.5	8	0.049	2.0
3	50	3.0	8	0.049	2.0
4	50	3.0	60	0.049	2.0

Table II. Effect of Cyanide Strength

Test No.	NaCN Equivalent, Pct	Assay of Products, Cu, Pct			Cu Extracted, Pct
		Filtrate	Residue	Feed (Calc.)	
5	0.125	0.041	0.017	0.051	66.7
6	0.187	0.043	0.015	0.050	70.6
7	0.250	0.046	0.013	0.051	74.6

Table III. Effect of Leaching Time

Test No.	Time, Min	Assay of Products, Cu, Pct		Cu Extracted, Pct
		Filtrate	Residue	
8	2	0.034	0.023	55.8
9	5	0.037	0.020	61.2
10	10	0.040	0.017	66.6
7	15	0.046	0.013	74.6

Table IV. Analysis of Cyanide Leach Solution

Total NaCN (dist.)	0.235 pct
NaCNS	0.015 pct
Cu	0.046 pct
Zn	0.018 pct

Table V. Effects of $CuSO_4$ and Cu-Bearing Cyanide Leach Solution on Activation of Sphalerite

Test No.	Activator	Product	Wt, Pct	Assay Zn, Pct	Distribution Zn, Pct
11	None	Head (calc.)	100.00	4.51	100.00
		R. conc.	2.85	3.51	2.22
		Tail	97.15	4.54	97.78
12	Copper sulfate	Head	100.00	4.58	100.00
		R. conc.	9.96	44.41	96.85
		Tail	90.02	0.16	3.15
13	Cu cyanide leach	Head	100.00	4.71	100.00
		R. conc.	2.73	2.70	1.36
		Tail	97.27	4.78	98.64

Table VI. Cyanide Balance

	Zinc Conc., Lb Per Ton	Percent of Total
NaCN equivalent added to leach	4.17	100.0
Total NaCN equivalent at end of leach	3.92	94.0
NaCN regenerated	3.67	87.9
NaCN equivalent consumed	0.50	12.1

A microscopic examination of the leached zinc concentrate from test 7 showed it to be relatively free of chalcopyrite.

Analysis of Leach Solution: An analysis of the leach solution from test 7 is shown in Table IV. Total NaCN (free plus complexed) was determined by distilling, with boiling, 10 pct HCl and trapping the liberated HCN in 1 pct NaOH solution. The other determinations were made by the usual methods.

Ninety-four percent of the original cyanide used for leaching reported as distillation NaCN. This includes, in addition to residual free NaCN, cyanide in complexes such as $Na_2Cu(CN)_3$, $Na_3Cu(CN)_4$, and

Table VII. Distribution of Copper in Acid Solution

	Zinc Conc., Lb Per Ton	Percent of Total
Total Cu leached out of Zn concentrate	0.77	100.0
Cu as soluble $CuSO_4$	0.43	55.8
Cu as insoluble CuCN	0.21	27.3
Cu as insoluble CuCNS	0.13	16.9

Table VIII. Activating Effect of $CuSO_4 \cdot 5H_2O$

Test No.	$CuSO_4 \cdot 5H_2O$, Lb Per Ton	Product	Wt, Pct	Assay Zn, Pct	Distribution Zn, Pct
11	None	Head (calc.)	100.00	4.51	100.00
		R. conc.	2.85	3.51	2.22
		Tail	97.15	4.54	97.78
14	0.10	Head	100.00	4.47	100.00
		R. conc.	4.45	18.14	18.07
		Tail	95.55	3.83	81.93
15	0.20	Head	100.00	4.43	100.00
		R. conc.	6.11	41.38	57.13
		Tail	93.89	2.02	42.87
16	0.40	Head	100.00	4.57	100.00
		R. conc.	9.56	46.48	97.22
		Tail	90.44	0.14	2.78
12	0.60	Head	100.00	4.58	100.00
		R. conc.	9.98	44.41	96.85
		Tail	90.02	0.16	3.15

Table IX. Activating Effect of Copper-Bearing Liquor

Test No.	Cu liquor $CuSO_4 \cdot 5H_2O$ Eq., Lb Per Ton	$CuSO_4 \cdot 5H_2O$, Lb Per Ton	Product	Wt, Pct	Assay Zn, Pct	Distribution Zn, Pct
17	0.30	None	Head	100.00	4.47	100.00
			R. conc.	10.70	40.17	96.26
			Tail	89.30	0.19	3.74
18	0.30	0.10	Head	100.00	4.46	100.00
			R. conc.	10.72	40.55	97.40
			Tail	89.28	0.13	2.60
19	0.30	0.20	Head	100.00	4.60	100.00
			R. conc.	10.63	41.79	96.50
			Tail	89.37	0.18	3.50
20	0.30	0.40	Head	100.00	4.77	100.00
			R. conc.	10.70	43.17	96.81
			Tail	89.30	0.17	3.19

Table X. Reagent Requirements Per Ton of Zinc Concentrates

NaCN eq.	0.5 lb
H_2SO_4	2.5 lb
NaOH	3.0 lb
or CaO	2.1 lb

$Na_2Zn(CN)_4$.[2] During leaching, 3.7 pct of the cyanide was converted to NaCNS. The remaining 2.3 pct probably represents mechanical loss and loss of HCN from hydrolysis.

By calculation, the solution contained at least 0.043 pct free NaCN equivalent (17.2 pct of the original cyanide added). This was determined by calculating the amount of cyanide complexed by the copper and zinc as $Na_2Cu(CN)_4$ and $Na_2Zn(CN)_4$ and subtracting this amount from the total cyanide determined by distillation.

Effect of Cyanide Leach Solution on Activation of Sphalerite: Two flotation tests were run in which the activating effects of copper sulfate and the copper-bearing cyanide leach solution (analysis Table IV) on sphalerite flotation were compared. In test 12, 0.6 lb per ton $CuSO_4 \cdot 5H_2O$ was used, while in test 13 a volume of cyanide leach solution containing an equal amount of copper was used. For comparison, test 11 was run using no copper compound whatsoever. The other conditions of the tests were the same as described under Flotation Procedure.

The results in Table V show that copper-bearing cyanide leach solution of the type shown in Table IV had no activating effect on sphalerite.

Regeneration of Cyanide in Leach Solution: As stated earlier, best leaching results were obtained with a 0.25 pct NaCN equivalent solution, equal to 4.17 lb NaCN equivalent added per ton of zinc concentrate leached. The feasibility of regenerating this cyanide, or part of it, was investigated with a view to: 1) reducing cyanide cost, and 2) using the copper-bearing solution remaining after cyanide regeneration for activation of the sphalerite in rougher flotation.

From the cyanide-leaching of zinc concentrate 150 ml of solution, having the analysis shown in Table IV, was transferred to a 500-ml bottle. This bottle was connected to an air supply on one side and to two similar bottles in series on the other side, each containing 1 pct NaOH solution. The cyanide leach solution was acidified to pH 3 by the addition of 3 lb H_2SO_4 per ton of solution, or 2.5 lb per ton of zinc concentrate. Air was bubbled through at room temperature at the rate of 13 cu ft per hr for 2 hr, the evolved HCN being trapped in the NaOH solutions. These solutions were titrated for NaCN content with $AgNO_3$, with KI as indicator.

A balance of the cyanide added, recovered, and consumed is shown in Table VI. The net consumption of cyanide is 0.50 lb NaCN equivalent per ton of zinc concentrate leached.

Examination of Leach Liquor after Regeneration: The acid leach liquor, after being stripped of HCN, contained a pale buff precipitate. This was filtered off and the precipitate and filtrate were assayed for copper content.

As may be noted from Table IV, the cyanide leach solution going to regeneration assayed 0.046 pct Cu; this calculates to 0.77 lb of Cu (equivalent to 3.08 lb $CuSO_4 \cdot 5H_2O$) per ton of zinc concentrate leached. The same amount naturally remained in the acid solution after HCN regeneration, 45 pct being distributed in the buff precipitate and 55 pct in the acid filtrate. An analysis of the buff precipitate showed it to be approximately 60 pct CuCN and 40 pct CuCNS.

Liquor: After being stripped of HCN, the copper-bearing liquor was compared with copper sulfate as an activator for sphalerite in the zinc rougher float.

As mentioned earlier, the amount of $CuSO_4 \cdot 5H_2O$ used in practice is 0.6 lb per ton of feed to flotation. To determine the optimum amount required under laboratory conditions a series of flotation tests was run in which the $CuSO_4 \cdot 5H_2O$ was varied from zero to 0.6 lb per ton of feed. The results are shown in Table VIII. Best results were obtained with 0.4 lb per ton of ore.

In a second series of tests copper-bearing liquor was used alone, and in conjunction with $CuSO_4 \cdot 5H_2O$, to activate sphalerite. The amount of copper-bearing liquor used in each test was equivalent to 0.3 lb $CuSO_4 \cdot 5H_2O$ per ton of zinc feed; this included the precipitated CuCN and CuCNS. Additional amounts of $CuSO_4 \cdot 5H_2O$ vary from 0.1 to 0.4 lb per ton.

As may be noted from the results in Table IX, good activation of sphalerite was obtained with copper-bearing liquor alone, equivalent in copper content to 0.3 lb $CuSO_4 \cdot 5H_2O$; with this amount, plus 0.1 lb $CuSO_4 \cdot 5H_2O$, the results compared favorably with the best results using $CuSO_4 \cdot 5H_2O$, i.e., 0.4 lb per ton.

Reagent Requirements: The reagent consumption for cyanide leaching of the copper and for cyanide regeneration are summarized in Table X.

On the credit side there is 0.77 lb of Cu recovered in the acid solution left after cyanide regeneration. This is equivalent to 3.1 lb $CuSO_4 \cdot 5H_2O$ per ton of concentrate, all of which is available for sphalerite activation at the head of the circuit.

SUMMARY AND CONCLUSIONS

1) The copper content of a zinc rougher concentrate was lowered from 0.05 to 0.013 pct by leaching for 15 min with Aero Brand cyanide solution containing the equivalent of 0.25 pct NaCN. The amount of zinc extracted at the same time was insignificant.

2) Relatively strong solutions of ammonia were ineffective solvents for the copper in the zinc concentrate.

3) The cyanide leach solution contained free cyanide in addition to copper and zinc cyanogen complexes; it also contained a small amount of thiocyanate. This solution had no activating effect on sphalerite in flotation.

4) The cyanide in the leach solution was regenerated by treatment with sulfuric acid at room temperature. Of the total cyanide used for leaching, 4.17 lb NaCN per ton of zinc concentrate, 3.67 lb or 87.9 pct was regenerated.

5) The acid solution remaining after cyanide regeneration contained a buff precipitate which consisted of CuCN and CuCNS. This precipitate accounted for about 45 pct of the copper leached out of the zinc concentrate. The remaining 55 pct was copper sulfate. In equivalent amounts the copper-bearing acid solution was as effective as copper sulfate for sphalerite activation.

6) Reagent requirements for cyanide leaching and cyanide regeneration were 0.5 lb NaCN equivalent, 2.5 lb H_2SO_4, and 3.0 lb NaOH (or 2.1 lb CaO) per ton of zinc concentrate treated. On the credit side, the equivalent of 3.1 lb $CuSO_4 \cdot 5H_2O$ was produced per ton of concentrate.

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ENERGY INPUT AND SIZE DISTRIBUTION IN COMMINUTION

by R. SCHUHMANN, JR.

Distribution of material in the fine sizes of a comminution product generally is well represented by the empirical equation[1]

$$y = 100 \left(\frac{x}{k}\right)^{\alpha} \qquad [1]$$

in which y = cumulative percent finer, x = particle size, α = distribution modulus, and k = size modulus.

Charles[2] found that the energy consumption in comminution is usefully expressed by another empirical relation,

$$E = A\, k^{(1-n)} \qquad [2]$$

in which E = energy input per unit volume of material, A = a constant, k = size modulus based on Eq. 1, and n = a constant; $(1\text{-}n)$ is the slope of a plot of log E vs log k. Holmes[3] has presented energy equations similar to Eq. 2.

The constants α and n in Eqs. 1 and 2 have been shown to depend both on the nature of the material and on the comminuting device. Moreover, Charles showed that within experimental error α and n are

$$\alpha - n + 1 = 0 \qquad [3]$$

Combining Eqs. 2 and 3,

$$E = A\, k^{-\alpha} \qquad [4]$$

In the first sections of this article it is shown that the energy equation, Eq. 4, can be derived directly from the size distribution equation for the fine sizes, Eq. 1. The derivations are made without assuming any of the specific relationships between energy and particle size which have been common in previous literature. For comminution processes in which Eqs. 1 and 4 adequately represent the experimental data, the constant A in Eq. 4 is found to be a simple and useful inverse measure of grindability. That is, A is the energy consumption per unit volume of comminution product finer than unit size as determined from the straight line portion of the log-log plot of the size distribution. These considerations all lead to a unifying hypothesis of comminution mechanism from which both Eq. 1 and Eq. 4 can be derived. Finally, it is pointed out that this hypothesis raises serious questions as to the significance of the Rittinger hypothesis, the Kick hypothesis, and other theories in which energy numbers are systematically assigned to various size fractions of comminution products in order to calculate theoretical energy consumptions.

Derivation of the Energy Equation from the Size Distribution Equation: For simplicity, consider the comminution of 100 volumes of a feed material of relatively uniform particle size. The comminution process may be considered as the summation of many individual and independent *comminution events*. The extent of comminution is most easily expressed as the number of comminution events, z. In the first derivation, the key assumption is that the characteristics of the comminution events in a given crushing or grinding process are substantially constant and do not vary with the progress of the comminution process. Accordingly the characteristics of an average comminution event may be defined. In one such event, a quantity of energy δE is applied to a single particle of size f and volume δv. The crushing of this particle produces fine particles with a size distribution similar to that given by Eq. 1:

$$y_e = 100 \left(\frac{x}{k_e}\right)^{\alpha_e} \qquad [5]$$

In this equation y_e, α_e, and k_e are used to characterize the product of an individual comminution event rather than the product of the comminution process as a whole. In using Eq. 5, we will not be concerned with values of x close to the feed size f and will therefore assume only that the equation is applicable to the finest sizes of the material. In 100 volumes of total product, the actual volume of product finer than x from a single comminution event, or δy, is given by

$$\delta y = \delta v \frac{y_e}{100} = \delta v \left(\frac{x}{k_e}\right)^{\alpha_e} \qquad [6]$$

The total volume of material below size x, resulting from z events, is then given by

$$y = z\,(\delta y) = z\,(\delta v) \left(\frac{x}{k_e}\right)^{\alpha_e} \qquad [7]$$

Eq. 7 reduces to Eq. 1 when we let

$$\alpha_e = \alpha \quad \text{and} \qquad [8a]$$

$$z = \frac{100}{\delta v} \left(\frac{k_e}{k}\right)^{\alpha} \text{ or } k = k_e \left(\frac{z\delta v}{100}\right)^{-\frac{1}{\alpha}} \qquad [8b]$$

Eq. 8a shows that the distribution modulus of the comminution product is the same as for the product of an individual comminution event. Eq. 8b shows how the size modulus of the comminution product k varies with the extent of comminution as measured by the number of events, z, or as measured by the fraction of the feed actually subjected to comminution, $\frac{z\delta v}{100}$.

The energy input to 100 volumes of total feed, or $100E$, is the sum of the energy inputs for all the comminution events:

$$100E = z\,(\delta E) \qquad [9]$$

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Eliminating z between Eqs. 8b and 9,

$$E = \frac{\delta E}{\delta v}\left(\frac{k}{k_o}\right)^{-\alpha} \qquad [10]$$

If now we let $A = \frac{\delta E}{\delta v} k_o^{\alpha}$, we obtain Eq. 4:

$$E = A k^{-\alpha} \qquad [4]$$

Thus the constant A in Charles' empirical energy equation is a characteristic constant for a single comminution event. That is, A is the product of the energy input per unit volume, $\frac{\delta E}{\delta v}$, and k_o^{α}, where k_o and α express the two size distribution parameters for a single event. Thus it is proved that the exponent $(1-n)$ in Charles' empirical energy equation (Eq. 2) must be equal to $-\alpha$, where α is the slope of the log-log size distribution plot for the fine sizes.

Generalized Derivation for a Complex Comminution Process: The derivation in the preceding section was based on the model of a comminution process as a summation of many substantially identical comminution events. To obtain a more general and less restrictive derivation, it is necessary to take into account the fact that the most practical comminution processes will involve a whole range of comminution events, with varying energy input, varying feed particle sizes, and varying size distributions. However, with a given feed material and given comminution device, it is reasonable to expect that all these different kinds of events will belong to the same family and possibly might be described by one equation. The best available data on energy input and size distribution for single comminution events seem to be Charles'[2] data for impact of projectiles on glass cylinders and Hukki's[4] pendulum-crusher data on single particles. Charles showed that these data for single comminution events conform to an empirical equation very similar to Eq. 5. That is, if δE_i is the energy input, δv_i the volume of the particle crushed, and k_i the size modulus of the product, all for a given kind of event i, the various kinds of events in a family are governed by

$$\frac{\delta E_i}{\delta v_i} = A k_i^{-\alpha} \qquad [11]$$

in which A and α are constants characteristic of the combination of material and comminution device. Charles demonstrated the validity of this relation for single comminution events by plotting log $\frac{\delta E_i}{\delta v_i}$ against log k_i. He found these graphs to be straight lines with slopes of $-\alpha$, where α, within experimental error, was the characteristic distribution modulus for the size distributions of the crushed products.*

* Hukki's results for NaCl and for galena gave straight lines in the plots of log $\frac{\delta E_i}{\delta v_i}$ against log k_i, but the slopes were somewhat flatter than would have been predicted from the size distribution plots. This deviation may be attributed to the pronounced cleavage habits of rock salt and galena.

Assuming now that the various kinds of comminution events in a complex comminution process are governed by Eq. 11, we can calculate the size distribution and energy consumption for the complex process by making appropriate summations over all the kinds of events. Letting z_i represent the total number of comminution events of kind i, the cumulative percent finer is given by summing over all i's (compare with Eq. 7):

$$y = \sum_i z_i \delta v_i \left(\frac{x}{k_i}\right)^{\alpha} = x^{\alpha} \sum_i z_i \delta v_i k_i^{-\alpha} \qquad [12]$$

Comparison with Eq. 1 shows that the size modulus of the entire comminution product, or k, is given by

$$100 k^{-\alpha} = \sum_i z_i \delta v_i k_i^{-\alpha} \qquad [13]$$

Similarly, the energy summation becomes (compare with Eq. 9):

$$100E = \sum_i z_i \delta E_i = \sum_i z_i \delta v_i \frac{\delta E_i}{\delta v_i} \qquad [14]$$

Substituting Eq. 11 in Eq. 14,

$$100E = \sum_i z_i \delta v_i A k_i^{-\alpha} = A \sum_i z_i \delta v_i k_i^{-\alpha} \qquad [15]$$

Eliminating the identical summations between Eqs. 15 and 13, we obtain

$$E = A k^{-\alpha} \qquad [4]$$

which is the same equation as derived previously for a simple comminution process made up of z identical comminution events. In the derivation just completed, we have not assumed identity of comminution events, but only that their characteristics are governed by Eq. 11 in accordance with the data of Charles and Hukki for single comminution events.

Measurement of Grindability: If Eqs. 1 and 4 are combined to eliminate k, we obtain

$$E = A \frac{y}{100} x^{-\alpha} \qquad [16]$$

This equation states that the energy input is directly proportional to the cumulative percent finer than any given size x. If particle size is expressed consistently in millimeters, this relation can be simplified to

$$E = A \frac{y_{1\,mm}}{100} \qquad [17]$$

in which $y_{1\,mm}$ is the cumulative percent finer than 1 millimeter. The value of $y_{1\,mm}$ should be read, of course, from the straight line that represents the size distribution of the fine sizes on a plot of log y vs log x. Grindability may now be conveniently defined as the reciprocal of A. Then Eq. 17 provides a simple measure of *grindability* $(1/A)$ *as the volume of comminuted material finer than unit size produced per unit of energy expended.* When this definition of grindability is used, it should be kept in mind that calculation of the volume of material finer than unit size will require extrapolation of the straight-line portion of the log-log size distribution plot when the experimentally measured portion of the straight line does not encompass unit size. For finely comminuted materials, that is, materials with the size modulus k less than 1 mm, $y_{1\,mm}$ as determined by graphical or analytical extrapolation will be greater than 100 pct. The resulting minor difficulty in visualizing the physical meaning of A could be avoided by simply choosing a smaller unit (for example, a micron) for expressing particle size, but such a choice seems less realistic for expressing

grindability over the whole range from coarse crushing to fine grinding.

The proposed measure of grindability is not new and is substantially equivalent to such common and practically useful grindability indexes as "tons −200 mesh produced per horsepower-hour."* However, it has now been shown that such indexes are fundamentally sound for comminution processes in which the size distribution is governed by Eq. 1 in the fine sizes and in which the energy input conforms to Eq. 4.

* To be fully consistent with the definition of grindability afforded by Eq. 17 the "tons −200 mesh per horsepower hour" should be calculated on the basis of the percentage −200 mesh read from the straight line portion of the log-log size distribution plot rather than on the basis of the actual percentage −200 mesh.

A Comminution Hypothesis: Up to this point, the discussion has explored a variety of consequences of the purely empirical observation that in the fine sizes of a comminution product the size distribution is adequately represented by Eq. 1. Now a further step will be attempted, namely, the formulation of an hypothesis about the mechanism of comminution from which the various so-far empirical equations governing size distribution and energy input might be straightforwardly derived.

Comminution of a brittle, isotropic, non-cleavable particle involves a rapid sequence of 1) application and storage of elastic energy, 2) initiation of cracking, and 3) energy dissipation associated with a systematically branching and intersecting system of cracks. If the original particle were reassembled with every fragment in its original position, the fracture pattern or geometrical arrangement of branching and intersecting cracks could be observed. The fracture pattern may be imagined as having two parts, as follows: One kind of fragments of relatively large size will be bounded by extensive cracks starting at the surface of the original particle or at imperfections within the original particle. In total weight or volume these larger fragments may account for a relatively large fraction of the original particle. However, the formation of these fragments results from the initial cracks and probably dissipates only a very small, probably negligible portion of the total energy. The second kind of fragments to be observed in the reconstructed fracture pattern consists of the relatively fine fragments formed by systematic branching and intersection of cracks. This portion of the fracture pattern develops in such a way that the length of a given crack from one branch to the next continues to decrease systematically in a geometric progression. Possibly this progressive decrease in crack length is associated with a progressive concentration of stored elastic energy in the region ahead of the cracks. In any event, this systematic cracking produces a fracture pattern and associated fragments which can be characterized by the geometric constant α, which is $\frac{\partial \log y}{\partial \log x}$. Since this portion of the fracture pattern is always geometrically the same for a given material and given comminution device, the overall energy dissipation is proportional to the volume of material subjected to the crack branching process or, more conveniently, to the amount y below a given size x. This proportionality can be expressed by the relation $\frac{\partial \log E}{\partial \log y} = 1$.

The reader can readily verify that the size distribution relation given in Eq. 1 and the energy relation in Eq. 4, as well as other equations presented earlier, can all be derived from the two differential equations resulting from the above hypothesis of comminution mechanism, namely

$$\left(\frac{\partial \log y}{\partial \log x}\right)_x = \alpha \qquad [18]$$

$$\left(\frac{\partial \log E}{\partial \log y}\right)_x = 1 \qquad [19]$$

Energy vs Particle Size: The analysis of comminution fundamentals presented in this article makes no use of the empirical equation relating energy directly to size, which has been common in the previous literature:

$$dE = -C\frac{dx}{x^n} \qquad [20]$$

in which dE is the energy required to produce an infinitesimal size change dx, x is the particle size, and C and n are constants. Charles[2] combined this equation with Eq. 1 to derive Eq. 2. However, as Charles himself pointed out, his derivation is not valid for the particular case when $\alpha - n + 1 = 0$ and $E = Ak^{-\alpha}$, which now seems to be the important case. In fact, it can be shown that if Eq. 1 and Eq. 4 are both valid for the experimental data, then the determination of the exponent n in Eq. 20 from these data is impossible. Moreover, Rittinger's hypothesis, Kick's hypothesis, and Bond's hypothesis all work equally well in assigning theoretical energy requirements on the basis of size distribution data. The reason for this indeterminancy is most easily clarified by re-examination of Eq. 17. This equation shows that the energy input is proportional to the weight of material finer than 1 mm. This proportionality is achieved regardless of how energy numbers are assigned to the various individual size fractions that make up the −1-mm material. Thus it becomes understandable how both the adherents to Rittinger's hypothesis and the adherents to Kick's hypothesis have for many years continued to find some experimental grounds for their respective methods of calculating energy consumption from sizing analyses. Also it is clear that Bond[3] has had no difficulty in finding experimental grounds for still a third theory. However, on the basis of the work described in the present article, it might be concluded that further attempts to prove any one or all of these energy-number hypotheses will prove meaningless.

Some readers (like the author) may find it difficult to give up the idea of an energy-number approach to calculation of theoretical comminution energy, whether their numbers are Rittinger numbers proportional to $\frac{1}{x}$, Kick numbers proportional to $\log \frac{x_o}{x}$, or Bond numbers proportional to $\frac{1}{x^{1/2}}$. These readers may find it helpful to think of comminution roughly from the following point of view: Any actual comminution product may be regarded as a mixture of "finished" comminuted material and coarse material not yet completely comminuted. Any comminution process simply converts the coarse material into *finished* material but does not change the size distribution or average size of the finished

material itself. Only the relative proportions of coarse material and *finished* material are changed, and it is these changes in relative amounts of coarse and fine material that account for the continually decreasing average particle size of the overall product during comminution.

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MEASUREMENT OF CEMENT KILN SHELL TEMPERATURES

by R. E. BOEHLER and N. C. LUDWIG

At Buffington Station, Gary, Ind., Universal Atlas Cement operates fourteen 8 x 10½ x 155-ft cement kilns in mill 6 and two 11 x 360-ft kilns in the Harbor plant. The No. 11 and 12 kilns in mill 6 are equipped with Manitowac recuperator sections.

This report describes studies in measuring exterior shell temperatures on several of these kilns and the development of a traveling radiation pyrometer with certain novel features.

Preliminary Work: At first various temperature-sensing devices were placed on the steel shell: 1) crayons with calibrated melting points, 2) colored paints with temperature-calibrated pigments, 3) aluminum paints with temperature-calibrated binders, and 4) metal-stem dial thermometers.

The colored paints and aluminum paints failed to indicate the temperatures correctly. The crayons and thermometers did indicate fairly correct temperatures, but it proved impossible to apply enough of these on the shell to detect all the potential areas where hot spots might develop. Furthermore, considerable labor was required to apply these sensors and read the temperatures. Consequently no further work was done with these devices.

Formation of Hot Spots: In the burning or clinkering zone of a cement kiln, the thickness of the protective coating and thickness of the brick govern the amount of heat transmitted to the steel kiln shell. Usually the protective coating consists of 4 to 8 in. of fused cement clinker.

The formation of a hot spot is usually caused by loss of coating, that is, localized areas of the coating become thin or fall away from the refractory. This is generally caused by excessive temperature in the burning zone over a fairly long period of time. It may also be caused by a sudden thermal change in the burning zone. Variations in raw feed composition and in feed rate require changes in the fuel and air rates, and when these are not appropriately altered, conditions may develop in the kiln that will result in loss of coating.

Luminescence on the kiln shell indicates that a hot spot has developed to a point that usually alters the refractory's thermal conductivity properties. When this thermal weakness zone occurs in the burning zone of the kiln, constant vigilance is required to protect it by maintaining proper coating. Even so, it has been the writers' experience that within a period of several days to about four weeks the hot spot usually recurs with greater severity. This necessitates shutting down the kiln and rebricking the affected area.

One of the prerequisites of a good burnerman is the ability to maintain a protective coating despite the many variables in operation. When he knows that it is getting thin or that an area has dropped off, he reduces the firing rate and kiln speed and brings feed into the affected area in an effort to rebuild the coating.

But when powdered fuel is burned, the atmosphere of the kiln may prevent the burnerman's observing the condition of the coating closely at all times without *taking off* the fire. It is not considered good practice to do this frequently, as it imposes a thermal shock on the coating and upsets operation of the kiln. To help the burnerman scan the shell of the kiln along the burning zone, therefore, a radiation pyrometer, connected to a potentiometric recorder, was mounted on a slowly moving steel cable.

The theory of operation, construction details, and adaptability of the radiation pyrometer are included in an excellent monograph[1] and also in a textbook.[2] Shell temperatures of the Atlas Cement kilns were measured with a Brown Instruments Div. low intermediate range Radiamatic unit, of range 200° to 1200°F, and a circular chart Electronik potentiometric recorder, of range 500° to 1000°F. In Bulletin 59095M the supplier publishes standard calibration data (millivolts vs degrees Fahrenheit) for this radiation pyrometer, These data, however, apply only to flat surfaces having emissivities of unity.

Calibration of Radiation Pyrometer for Use on Curved Surfaces: When applied to surface temperature measurements, the radiation pyrometer reading depends on the nature of the surface, the material of which it is composed, and also to some extent on the temperature of the surroundings. Although the present radiation pyrometer is designed to give a calibrated response under ideal (black body) conditions when used commercially, it must be calibrated empirically.

The calibration procedure, given below, follows that described by Dike (Ref. 1, pp. 38-39). Calibration tests on plane and curved surfaces showed that the response of the radiation pyrometer was very

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nearly the same on both. However, to duplicate conditions of usage more closely a curved surface was used in the calibration procedure. As shown in Fig. 1, the pyrometer is positioned to focus on a curved piece of ¼-in. steel plate approximately equal in radius to that of the cement kiln. Ironconstantan thermocouple wires are inserted through a small hole drilled in the center of the plate. The wires are then silver-soldered, and the solder is smoothed flush with the front surface of the plate. An acetylene flame is moved over the entire back of the plate to heat it to a uniform temperature. The thermocouple temperature is measured with a conventional potentiometer.

The reading of the potentiometric recorder is adjusted to the thermocouple temperature by adjustment of the instrument amplifier gain. The following are typical calibration data:

IC Thermocouple, °F	Recorder, °F	Difference, °F
520	520	0
600	600	0*
650	645	−5
700	695	−5
800	795	−5
900	895	−5
950	950	0
970	970	0

* Adjustment made at this point.

Although the steel plate was selected to have the same surface character as that of the cement kiln, it is realized that the emissivities of the two surfaces may not be the same. McAdams[2] gives the following values for normal total emissivity of steel surfaces:

	Temperature Range, °F	Emissivity Factor
Steel oxidized at 1110°F	390 to 1110	0.79
Sheet steel, strong rough oxide layer	75	0.80
Sheet steel, dense shiny oxide layer	75	0.82

On the basis of the above values, it is estimated that the instrument readings taken on the kiln shell are accurate within about ± 5 pct.

After the pyrometer is placed in service, it is necessary to clean it and check its calibration periodically. When there is a question about a certain reading, the operating personnel make a calibration spot check with temperature-calibrated crayons or with a duplicate pyrometer and recorder, now being used in a stationary position on kiln No. 11. About every 60 days the pyrometer is removed from the cable bracket, cleaned and inspected, and recalibrated according to the procedure described above.

Initial Tests with Radiation Pyrometer: These tests are surveys made by mounting the pyrometer in a pedestal and setting the pedestal at increasing intervals along the kiln shell.

Fig. 2 shows the results of one of these surveys made on kiln 12, mill 6. This kiln is equipped with a Manitowac recuperator. It may be observed that two hot spots were located, one a few feet behind the front tire and one about 15 ft past the back clinker ring.

Fig. 3 shows the results of one of the surveys made on kiln 1, Harbor plant. Four hot spots were found on the kiln shell between the nose of the kiln and the front tire. Metal-stem dial thermometers, range 200° to 1000°F, are installed on this kiln at

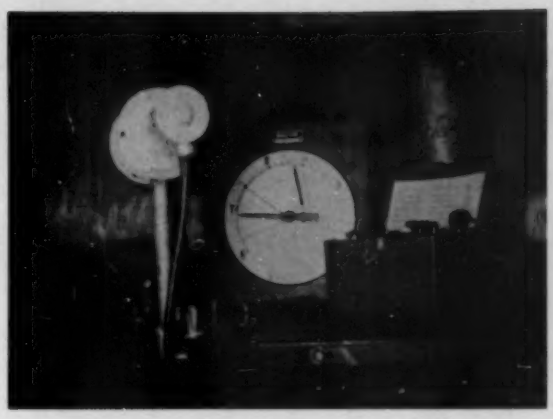

Fig. 1—Equipment for calibration procedure. The pyrometer is focused on curved piece of heated steel plate.

the points noted. The stems of these thermometers are inserted in short pieces of ¼-in. standard pipe welded to the shell. As shown by the data, these thermometers read about 90° to 130°F low, and the readings are not indicative of the development of a hot spot unless one develops in the immediate area of a thermometer.

In a number of instances initial work with the radiation pyrometer included watching a hot spot develop until it became red. At the start, the point at which a hot spot develops usually shows somewhat higher than average peripherical temperature at that location. The study of kiln No. 12 temperature charts showed that it usually takes about 45 min from the time a hot spot starts to form until it reaches the point of luminescence, 1000° to 1100°F. Thus the value of this instrument in guarding against hot spot formation was revealed by the initial tests.

Development of Traveling Mechanism: As the radiation pyrometer moves slowly over the length of the burning zone, temperatures are recorded on the chart, along with reference points used to indicate the pyrometer's position. Fig. 4 shows the general layout of equipment for moving the device over the kiln shell. The ⅜-in. steel cable is supported under tension on two single-groove pulleys located alongside the shell. The distance between the lens of the pyrometer and the burning zone section of the kiln shell is 20 in., and the diameter of the circular target area at this distance is estimated to be 1⅜ in. This is illustrated by Figs. 5-8.

The following provisions were incorporated in the system:

1) When the radiation pyrometer reaches the back end of its travel, the recorder pen goes off scale (maximum temperature), resuming its normal recording position when the pyrometer starts toward the front of the kiln. This furnishes a chart reference point, and by reference to the Travel vs Time Relations in Fig. 4 the position along the kiln is obtained for any particular chart temperature. At the normal kiln speed of 80 rph, the pyrometer moves 6 in. along the shell during each kiln revolution.

2) When the radiation pyrometer reaches a temperature preset by a limit switch in the recorder, the drive unit automatically stops and a neon light goes on. Warned by this signal, the burnerman takes the necessary precautions to alleviate the conditions

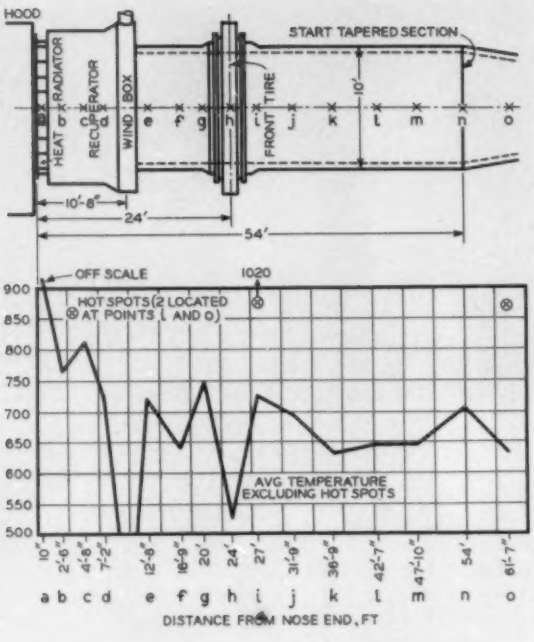

Fig. 2—Shell temperature survey with radiation pyrometer. Kiln No. 12, mill 6, Universal Atlas Cement Div.

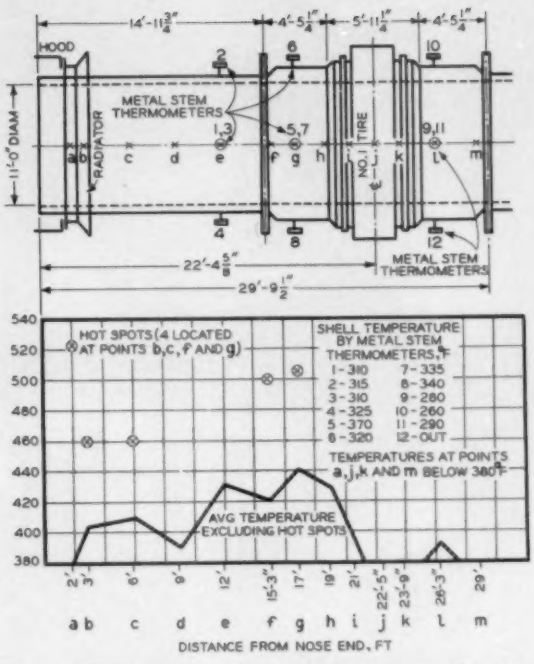

Fig. 3—Shell temperature survey with radiation pyrometer. Kiln No. 1, Harbor plant, Universal Atlas Cement.

causing the hot spot. He then starts the travel again by pushing a button located near the recorder.

Operating sequence of the wiring system, shown in Fig. 9, is as follows:

As the pyrometer travels toward the rear of the kiln, float switch 12 is in position *B*, contact *T* on time delay relay 1 is closed and motor contractor 4 is in closed position. Near the end of travel, float switch 12 is tripped to position *F*. This de-energizes the coil on contactor 4, stops the drive motor, and energizes time delay relay 2. After 8 sec this relay closes and energizes the coil on motor contactor 3, which starts the drive motor in opposite rotation. Also, near the end of travel, microswitch 5 is tripped, which de-energizes the coil on mercury switch 10. This opens the measuring circuit to the recorder and, by virtue of its special *burn-out* feature, activates the recorder to go off scale. After the pyrometer starts moving forward, microswitch 5 returns to its normal *on* position, thus closing the recorder measuring circuit and returning the pen to a recording position.

Limit switch 9 in the recorder is adjusted to open at a temperature in the range of 700° to 800°F. When the shell temperature reaches this value, switch 9 closes and energizes thermostatic relay 8. This opens the circuit to the coils of motor contactors 3 and 4 and time delay relays 1 and 2, stopping the drive motor and also closing the circuit to the neon bulb. Hence the pyrometer now measures only that temperature at the holding point.

When button 14 is pushed the pyrometer starts traveling again. This energizes the coils on relay 7 and time delay relay 6 and de-energizes the coil on thermostatic relay 8, causing the pyrometer to continue in the same direction it was going when it stopped. To short out push button 14 until a cooler area on the kiln is reached, time delay relay 6 is set to time out in about 3 min. However, if after 3 min the pyrometer is still on a hot spot of temperature above that of the set point of limit switch 9, the circuit will recycle through the recorder limit switch and stop the pyrometer. Push button 14 will now have to be pushed again to start travel.

Time delay relay 16 is used in the circuit to short out the recorder limit switch while the recorder is drawing a reference line at the end of travel. If this were not done, the limit switch would stop the travel of the pyrometer at the time the recorder was drawing a reference mark.

Charts: Figs. 10, 11, and 12 are charts showing typical kiln shell temperature recordings with continuous scanning. These show shell temperatures immediately after installation of a new brick lining and three and nine days later. It will be seen that the maximum shell temperature of 800°F for the new lining recedes to about 700°F after nine days of operation. This shows the insulating effect of the protective coating built up during that period.

Fig. 13 is a chart showing a typical recording when the pyrometer was stopped for a period of

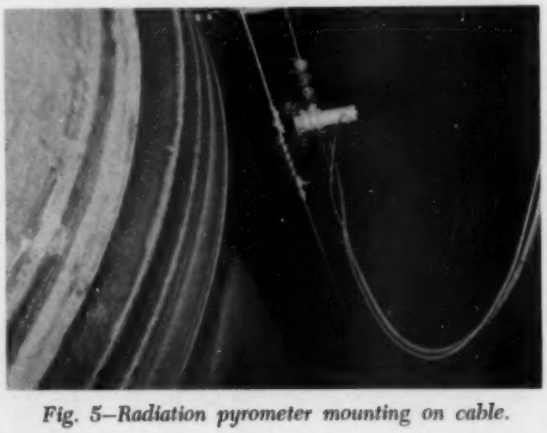

Fig. 5—Radiation pyrometer mounting on cable.

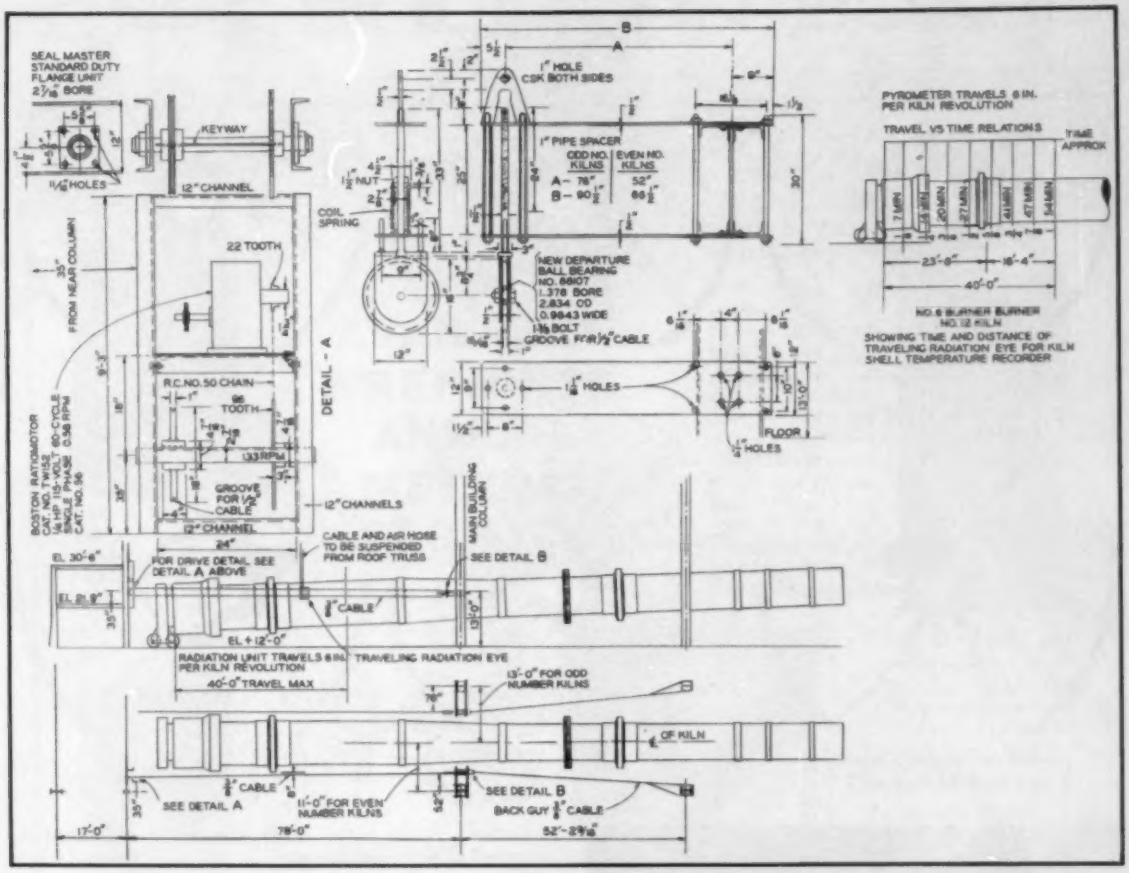

Fig. 4—Plan and detail of traveling radiation pyrometer.

about 5 hr on a hot spot. In this instance, the limit switch 9 was adjusted to open at 700°F. After 5 hr, the burnerman decided that the shell temperature at this particular spot was back to a safe value and reset the traveling mechanism.

Fig. 14 shows a special case in which the pyrometer was moved forward past its normal travel span to measure nose ring temperatures. These were high on this particular day because the clinker was improperly air-quenched as it passed over the recuperator section. This figure shows that after the nose ring temperature went down to safe values the pyrometer was restarted on its regular path of travel.

Fig. 15 is a typical recording of the pyrometer focused for 24 hr on an area where a hot spot de-

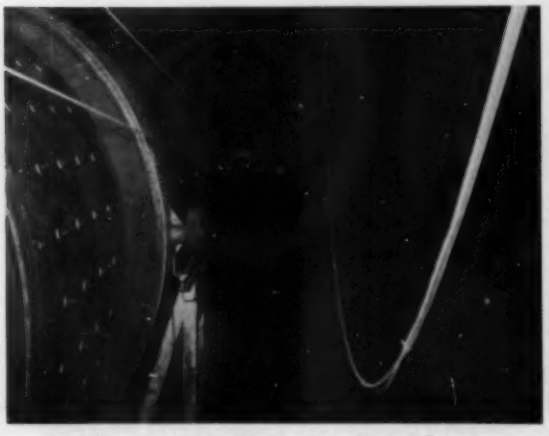

Fig. 6—Position of cable along kiln.

Fig. 7—Drive unit located at front of kiln.

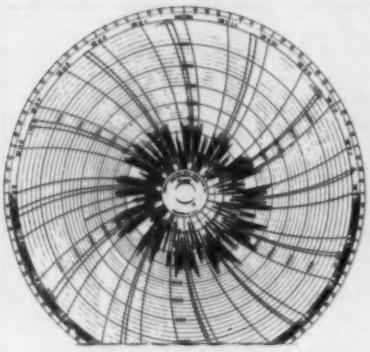

FIG. 10 – KILN 12, AUG. 14, 1958
NEW BRICK LINING

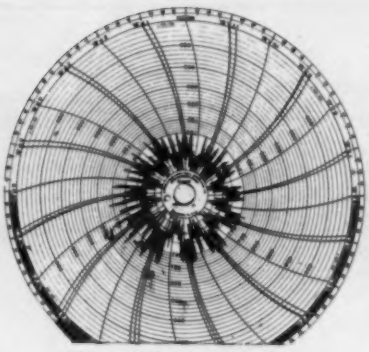

FIG. 11 – KILN 12, AUG. 17, 1958
THREE DAYS LATER

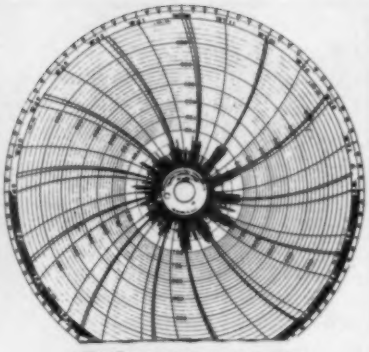

FIG. 12 – KILN 12, AUG. 23, 1958
NINE DAYS LATER

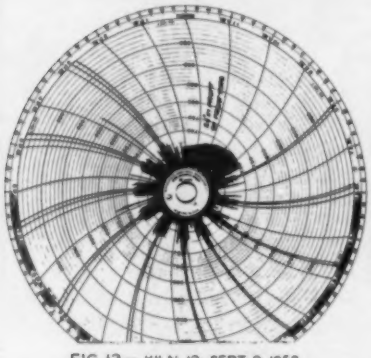

FIG. 13 – KILN 12, SEPT. 2, 1958
PYROMETER STOPPED
FOR 5 HR ON HOT SPOT

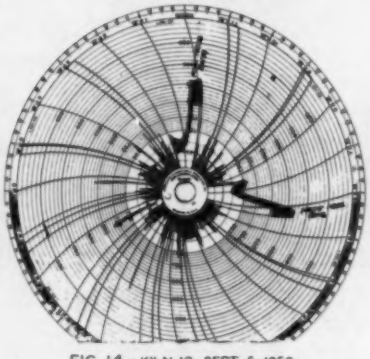

FIG. 14 – KILN 12, SEPT. 5, 1958
PYROMETER STOPPED
ON NOSE RING

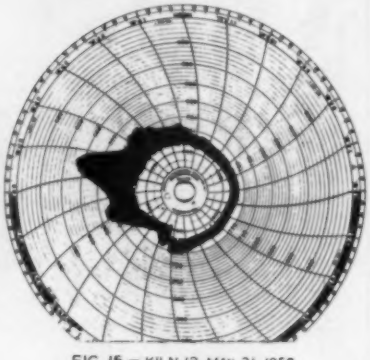

FIG. 15 – KILN 12, MAY 31, 1958
PYROMETER STOPPED
24 HR ON HOT SPOT

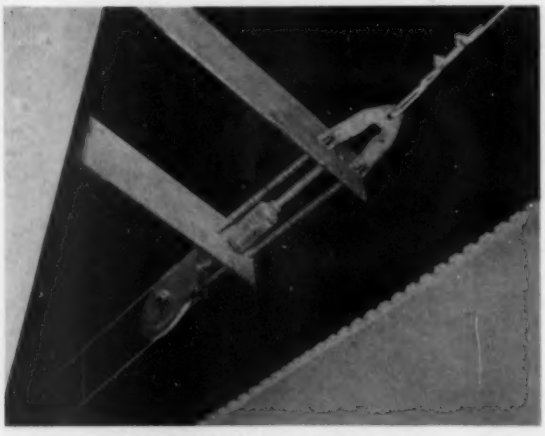

Fig. 8–Cable support, far end.

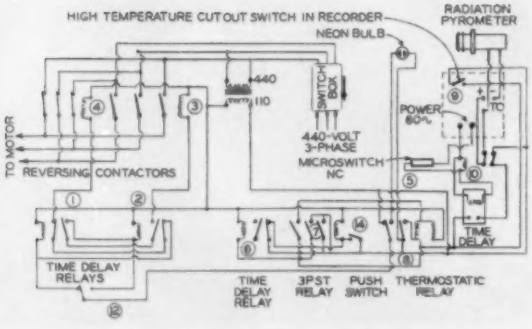

Fig. 9—Wiring for controlling traveling pyrometer.

veloped. It is noted that the shell temperature started to increase rapidly (at about 4:45 pm) fully 30 min before the maximum temperature was reached. This was a warning to the burnerman, who was able to prevent the spot from reaching luminescence (+1000°F). By reducing the firing rate and kiln speed and bringing more feed into the section, he brought the shell temperature back to normal for this area about 3 hr later.

Improvement in Kiln Operation: The decreasing frequency of kiln shutdowns are taken as criteria of improvement in the operation of kiln No. 12, mill 6:

March 13, 1957—Kiln was started with recuperator.

March 13 to Nov. 11, 1957—Tempilstiks were used to measure shell temperatures. During this nine-month period the kiln was down five times for replacement of brick in the burning zone.

Nov. 11, 1957 to June 17, 1958—A radiation pyrometer was mounted on a pedestal and visually sighted on the area corresponding to points *I* and *J* in Fig. 2. During this seven-month period the kiln was down twice for replacement of brick in the burning zone.

June 17 to Nov. 10, 1958—The radiation pyrometer was used on a traveling cable. During this five-month period the kiln was down twice for relining.

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[1] P. H. Dike: Temperature Measurements with Ray-O-Tubes. *Tech. Pub. EN-33B (1)*, Leeds and Northrup Co., January 1953.

[2] W. H. McAdams: *Heat Transmission*. McGraw-Hill Book Co., New York, 1933.

[3] *Temperature: Its Measurement and Control in Science and Industry*, vol. 2. Published for the American Institute of Physics by Reinhold Publishing Corp., New York, 1955.

Discussion of this article sent (2 copies) to AIME before March 31, 1960, will be published in MINING ENGINEERING.

SME BULLETIN BOARD

Reports of Your Technical Society

J. L. GILLSON

MINING ENGINEERING salutes AIME's President for 1960 on pages 116 and 117.

SME AVAILABLE PREPRINTS ANNUAL MEETING PAGE 178

JOHN G. WINGER, All-Institute Speaker at Annual Meeting

J. G. Winger, vice president of the Chase - Manhattan Bank in New York will discuss the "Future of the Petroleum Industry in the U. S. for the Decade 1960-1970" during the All-Institute session, Tuesday afternoon, February 16. His presentation will be a combination of slides and lecture.

MEETINGS

Past and future meetings of interest to SME'ers are covered in this issue. Turn to page 171 for a report on the Arizona Section annual meeting last December. On page 170, preliminary plans are reported for the Coal-St. Louis Section meeting in September and further details are given of the Alaska Mining, Minerals, and Petroleum Conference. The map serves as a reminder of the Pacific Northwest Regional Conference —Portland, Ore., April 28 to 30. For a "roster" of forthcoming 1960 meetings turn to "Drift" on page 115.

Page 171—AIME names Western Field Secretary.

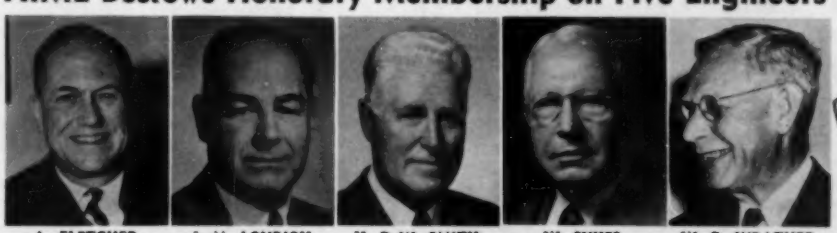
NEWSLETTERS . . .

- MBD'ers Digest page 175
- Rock in the Box page 173

Change of Address Personals Data Boxes page 187

Mineral Information Section Begins On Page 78

AIME Bestows Honorary Membership on Five Engineers



A. FLETCHER | J. M. LOVEJOY | H. DeW. SMITH | W. SYKES | W. R. WRATHER

AIME is honoring at the February Annual Meeting in New York five distinguished engineers for outstanding achievement in the fields of interest represented by the Institute. Those who will receive Honorary Membership, highest award the Institute can bestow, are: Andrew Fletcher, president, St. Joseph Lead Co.; John M. Lovejoy, New York consultant on oil investments; H. DeWitt Smith, formerly vice president of Newmont Mining Corp., Wilfred Sykes, formerly president of Inland Steel Co.; and William E. Wrather, former director of USGS.

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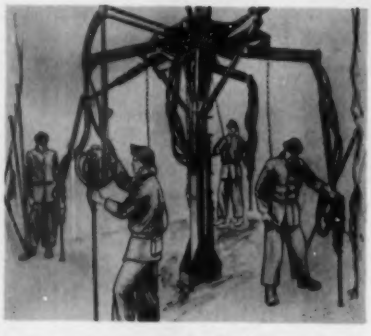

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Coal-St. Louis Section To Hold Joint Meeting On September 8 and 9

On September 8 and 9 the SME Coal Division and the AIME St. Louis Section will hold a joint meeting at the Chase-Park Plaza Hotels in St. Louis.

Preliminary meeting plans call for two technical sessions, covering coal, iron ore, and industrial minerals resources of the area. In addition there will be a field trip to the River King mine and coal preparation plant of the Peabody Coal Co.

William A. Weimer, Peabody Coal Co., is general arrangements chairman for the meeting; Gordon M. Bell, Aluminum Co. of America, is St. Louis Section Chairman; and J. D. Reilly, M. A. Hanna Co., is handling the Coal Division program.

Others who attended a planning session on January 19 for the meeting were F. S. Elfred, S. L. Jewell, H. C. McCullom, and E. E. Quenon, all Peabody Coal Co.; H. O. Zimmerman, Inland Steel Co.; George E. Keller, U. S. Steel Corp.; V. W. Buys, Mine Safety Appliances Co.; John Ong, Washington University; John C. Fox, SME; and H. N. Appleton, AIME.

Alaskans Will Convene At Conference in April

Featured speakers at the banquet to be held during the forthcoming Alaskan Mining, Minerals, and Petroleum Conference will be Joseph L. Gillson, 1960 AIME President, and James Boyd, vice president, exploration, Kennecott Copper Corp.

The conference, and annual event, will be held April 11 to 13 on the campus of the University of Alaska, and is being sponsored by the AIME Alaska and Southwest Alaska Sections, the University, and the CIM Yukon Section.

One of the main conference themes will be exploration. Other topics to be covered will be space tracking, new techniques in placer mining, foreign markets for Alaskan products, and the oil boom.

The conference committee, headed by Earl Beistline, dean, University of Alaska School of Mines, consists of James Crawford, U. S. Smelting, Refining and Mining Co.; Denny Breaid, Usibelli Coal Sales Corp.; Ted Matthews, Exploration Services Inc.; Bruce Thomas, USBM; and Maurice Butler, Butler Drilling Enterprises.

Alumni Meeting

The South Dakota School of Mines & Technology will hold an alumni dinner on Tuesday, February 16, during the AIME Annual Meeting. Place will be the East Room of the Sheraton-Atlantic Hotel; 6:00 pm.

Medallions of Merit Awarded at Arizona Annual Dinner Meeting

Tucson was the site of the annual meeting of the AIME Arizona Section on December 7. One of the highlights took place at the dinner when the University of Arizona presented 75th Anniversary Medallions of Merit to outstanding men in the mining field.

All functions were held at the Pioneer Hotel, beginning with registration and coffee for the ladies. In the morning three sessions covered mining geology, underground mining, and smelting.

Chairman of the mining geology session was Edward L. Jones, Bagdad Copper Corp. John W. Harshbarger of the University of Arizona presented the first paper entitled *Geologic Framework of Arizona as Related to Ground Water Supplies.* Eldred D. Wilson outlined his work with the Arizona Bureau of Mines, and Willard D. Pye discussed petroleum prospects in the state.

At the underground mining session Henry D. Clark of Phelps Dodge Corp. acted as chairman, introducing L. W. Towle, Apache Powder Co., who talked about the manufacture of explosives. D. L. Simpson followed with a study of the engineer trainee program at Ray, Arizona, Kennecott Copper Corp. The last paper was by E. H. Torgersen of Phelps Dodge on *Stoping Methods at Copper Queen.*

J. H. Halley led the smelting session with Leonard Klein of Phelps Dodge presenting the only paper on *Gaseous Reduction of Oxygen-Containing Copper.*

In the afternoon there were sessions on open pit mining and mineral dressing. Ben G. Messer, Duval Sulphur and Potash Co., was chairman in the ballroom for the open pit discussion and introduced three speakers: John E. O'Neill, Phelps Dodge Corp., *Drilling Methods and Equipment at New Cornelia Open Pit Mine;* R. W. Volpe and J. C. Price, General Electric Co., who discussed *Motorized Wheel Drive for Off-Highway Vehicles;* and Frank Buchella, Jr., Duval Sulphur and Potash Co., who talked about aerial mapping in determining evacuation quantities.

The mineral dressing session had C. B. Kettering as chairman with T. D. Henderson and Russell Salter as speakers. Milling problems and cyclones as primary classifiers were covered in their talks.

In the evening the banquet featured the election of officers and presentation of awards. Special highlight was the address by 1960 AIME President Joseph L. Gillson.

During the Arizona Section annual meeting, held in December, mining leaders called on Richard A. Harvill, president of the University of Arizona. From left to right are: Jack B. Pullen, assistant general manager, Phelps Dodge Corp.; T. Alfred Snedden, manager, Southwestern Mining Dept., Asarco; Benjamin R. Coil, vice president and general manager, Miami Copper Corp.; John C. Fox, SME Secretary; J. L. Gillson, E. I. du Pont de Nemours and Co. Inc. and AIME President-Elect; Thomas G. Chapman, dean emeritus, University of Arizona College of Mines; Dr. Harvill; James D. Forrester, dean, University of Arizona College of Mines; Allan B. Bowman, vice president and general manager, Banner Mining Co.; W. W. Little, manager, Bisbee Branch, Phelps Dodge Corp.; H. C. Weed, general manager, Inspiration Consolidated Copper Co.; and Joe B. Davis, president of the University of Arizona AIME Student Chapter.

Dancing completed the evening's entertainment.

Sixteen Arizona mining leaders received the Medallions of Merit for outstanding service to the state and to the development of the university's teaching and research programs. Among the recipients were the following officials of Phelps Dodge Corp.: W. C. Lawson, J. B. Pullen, and A. T. Barr (his award was presented in November at the University Homecoming celebration). C. R. Kuzell, retired vice president of Phelps Dodge and now president of Apache Powder Co., also was honored with a medallion.

Kennecott Copper Corp. recipients were A. P. Morris and R. W. Thomas. Inspiration Consolidated Copper Co. officials who were honored were P. D. I. Honeyman and H. C. Weed.

Benjamin R. Coil and R. W. Hughes of Miami Copper Corp. also received the awards. Mr. Hughes was vice president and general manager before he retired.

Other mining company winners are as follows: A. B. Bowman, Banner Mining Co.; J. F. Buchanan, San Manuel Copper Corp.; W. P. Goss, Magma Copper Corp.; Albert Mendelsohn, retired general manager and president of Cananea Consolidated Copper Corp.; T. A. Snedden, American Smelting and Refining Co.; and Charles F. Willis, consulting engineer.

ESPS Issues Employers, Employes Biweekly List

Engineering Societies Personnel Service has announced a new bulletin of *Engineers Available.* The new publication, issued in December 1959, will be distributed, free of charge, on a biweekly basis to several thousand employers in the eastern states. It contains a short synopsis of the experience of engineers who have registered with ESPS and who are seeking a new position. The new bulletin is part of an expanded ESPS program designed to increase the effectiveness of the agency's service to both employer and employe.

To receive copies, write to ESPS, 8 W. 40th St., New York 18, N. Y., and your name will be added to the mailing list. Engineers who are registered with ESPS, are entitled to a 35-word notice in the Bulletin. Forms for this purpose can be secured from the New York office. Identities of engineers described will not be given in the Bulletin.

Further plans call for extension of the publication to include the midwest and western ESPS offices.

AIME Appoints C. Hicks Western Field Secretary

AIME announces the appointment of Clifford J. Hicks as Assistant Secretary and Western Field Secretary, effective February 14. He succeeds the late Roy E. O'Brien in the post and will maintain his office in Salt Lake City.

Mr. Hicks is no stranger to AIME members, having served as secretary of the Montana Section for seven years, and is at present member of the executive committee of the Section. He has been a member of the AIME Council of Section Delegates for four years.

Mostly recently senior geologist of the Kelley Mine in Butte, Mr. Hicks has spent the majority of his professional career with The Anaconda Co. He joined Anaconda as junior mining engineer in the fall of 1947, becoming, successively, mining engineer, junior geologist, and senior geologist. Most of his time at Anaconda has been spent in a majority of the company's Butte mines.

A World War II veteran, Mr. Hicks was born in Milwaukee in 1921 and attended public schools there. He attended the University of Wisconsin, receiving a B.S. in geology.

Married in 1945, Mr. and Mrs. Hicks have a son John, age 11.

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ROCK IN THE BOX

Mining & Exploration Division

R. J. Lacy, Incoming M&E Chairman, Calls Attention to Division Services

(Editor's Note: *At the suggestion of J. C. Chandler, incoming chairman R. J. Lacy has prepared the following statement of his thoughts and aspirations for the Division in the coming year.)*

As incoming chairman of the Mining and Exploration Division, I should like to attempt to point out to the members of the Division the services and benefits now available to them and to present a few suggestions for the future.

Some of the services and benefits now available to you are as follows:

1) Just as the trend in the mining industry is toward integration, you now have a Division within the Society of Mining Engineers wherein the miners and the exploration people carry out integrated functions, rather than subdivided efforts.

2) Your Annual Meeting programs reflect this coordination in fewer total sessions and more joint sessions.

3) MINING ENGINEERING, your official SME magazine, has improved its service to you with your editorial section, *Rock in the Box*, the presentation of abstracts of both published and unpublished papers, and other features.

Some of you say that you do not know how M&E functions nor the current officers and committee members. Use your magazine. The Bylaws were published on pp. 1157-1159 in the *Rock in the Box* section of the October 1957 issue. The organization chart is presented in the same section on page 499 of the April 1958 issue. Your Division officers and committee members are presented in *Rock in the Box*. Your Annual Meeting programs are presented in your magazine as promptly and accurately as the actions of your part-time officers and committee members *and you* permit. The SME's general and Transactions editorial committees (see listing on *Drift* page) have been very active and are in process of proposing several changes that will improve even more the presentation of technical papers and articles.

You, as members of the M&E Division, do influence its organization and the trend of its policies. The reorganization indicated by the new Bylaws and charts were the result of your criticism. You are not governed by a closed corporation clique, as some of you appear to believe. Know your organization and officers by reading *Rock in the Box*, and your criticisms will be more effective, as you may then direct them through proper channels.

Your officers and committee men are part-time workers for you. Although Jack Fox, Secretary of the Society of Mining Engineers, does an excellent job of advising and prodding these officers, they are not always able to give you the service they would like to give and which you deserve. The work load of their regular jobs and their annual amateur status in the new Division assignments are certainly handicaps. I suggest, both in order to spread the work load and to allow more members of the Division to participate in M&E functions, that additional committees should be set up. I suggest further that committee members hold staggered two-year tenures in order to reduce amateur status on committees whose functions would justify such policy. We present and incoming officers have some ideas concerning additional committees. We invite the members to present theirs.—*R. J. Lacy*

Annual Meeting Events

Division members are reminded that the annual business meeting of M&E, held during the AIME Annual Meeting, will take place on Wednesday, February 17, in the East Room of the Statler Hotel, at 4:30 pm. The Division luncheon will be held on the same day, at 12:15 pm in the Statler's Gold Ballroom. Feature event on this occasion will be presentation of the Daniel C. Jackling Award to Louis B. Slichter, director of the Inst. of Geophysics, University of California. Dr. Slichter will give the Jackling Lecture later that afternoon. M&E'er Robert J. Linney will be honored at the AIME Annual Banquet, Wednesday.

EDITOR

Address news items to:

John W. Chandler, American Metal Climax Inc., 61 Broadway, New York 6, N. Y.

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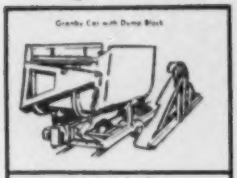

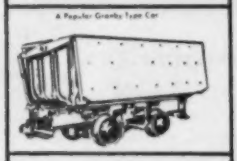

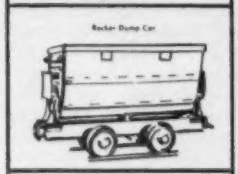

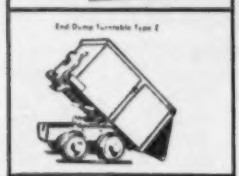

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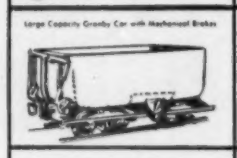

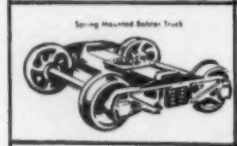

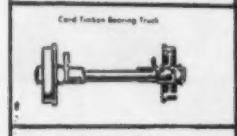

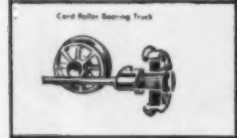

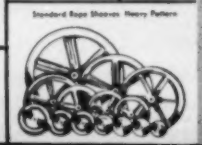

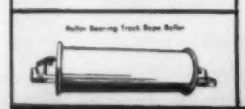

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National Clay Meeting Planned for Next Fall

On October 6, 7, and 8, next fall, the Ninth National Clay Conference will be held at Purdue University, Lafayette, Ind., under the auspices of the Clay Minerals Committee of the National Academy of Sciences-National Research Council.

Two symposia of invited papers will be given on the topics of *Engineering Aspects of Physico-Chemical Properties of Clays* and *Clay-Organic Complexes*. There will be general sessions of contributed papers. All those having contributions should contact J. L. White, chairman, Ninth National Clay Conference, Agronomy Dept., Purdue University, Lafayette, Ind., by June.

Blast Furnace Program Covers Coal, Iron Ore

The annual Blast Furnace, Coke Oven, and Raw Materials Conference of the Iron and Steel Division, The Metallurgical Society of AIME, will be held April 4 and 5 at the Palmer House in Chicago.

During the meeting, sessions on coal and iron ore beneficiation will contain papers of particular interest to SME members.

The Coal Session, under the chairmanship of J. R. Dietz and W. M. Matthews will be held Monday morning, April 4, and will cover the following topics: *Use of Coal Plasticity in Coke Plant Coal Blending* by W. G. Schulze and G. C. Soth, *Fine Coal Cleaning with the Circular Concentrator Table* by H. B. Charmbury, *Nature of Coking Coals and the Mechanism of Coke Formation* by N. Berkowitz, and *Technical and Economic Effects of Moisture in Coking Coals* by J. D. Doherty and J. Griffen.

The Iron Ore Reduction session under the chairmanship of H. U. Ross and G. G. Hatch will also be held on Monday morning, April 4. The following papers will be presented: *The Alan Wood H-Iron Plant* by R. A. Lubker, *Thermodynamics of Direct Reduction Processes* by Kun Li, *Kinetics of Hydrogen Reduction of Hematite* by W. A. Hockings, *Study of the Kinetics of Magnetic Roasting* by J. P. Hansen, G. Bitsianes, and T. L. Joseph, and *Direct Reduction of Fine Iron Concentrates in a Self-Agglomerating Fluidized Bed* by B. G. Langston and F. M. Stephens.

A paper on *Recent Developments in British and European Coal Carbonization Research* by G. W. Lee will be given at the Coke session on Monday afternoon.

During the session to be held on Tuesday afternoon, April 5, a film entitled *Development of the Zonguldak Coal Field in Turkey* will be shown by R. E. Zimmerman of the Paul Weir Co., Chicago.

PROMINENT ENGINEER NAMED AS RECIPIENT OF RICHARDS AWARD

Norman L. Weiss, recipient of the Richards Award for 1960, was born in Boston and educated in public schools there and in Philadelphia. He attended Boston English High School and graduated from the Massachusetts Institute of Technology with a degree of Bachelor of Science in 1923. The following year was spent at Pennsylvania State College teaching and doing graduate study under Dean E. A. Holbrook.

From 1924 until 1945, Norman Weiss was employed by the Dow Chemical Co., Great Western Div., in San Francisco, as a metallurgical engineer in field work representing their flotation reagents. During this period he covered the Southwest, Tri-State, Mexico, Central America, and all of South America.

In 1948 he returned to the employ of American Smelting and Refining Co. as milling engineer with offices in Salt Lake City. His work was comprised of supervision of the operations of company mills in the U. S., Peru, Bolivia, Nicaragua, Newfoundland, and the consulting services for other companies including Granby Consolidated, Triumph Mining Co., and other operations of American Smelting and Refining Co.

Perhaps one of the most prominent phases of his work was the design and construction of new mills for the company, namely, improvements to the Leadville, Colo., mill in 1948; a new 600-ton lead-zinc mill at Deming, N. M., built in 1949-1950; a new crushing plant at the Ground Hog mine, N. M., built in 1948; a new 1000-ton lead-zinc mill at the Van Stone mine near Northport, Wash., built in 1951-1952; a new 7500-ton copper mill at Silver Bell, Ariz., built in 1952-1954; a new 200-ton lead-zinc mill, Crested Butte, Colo., built in 1953; flowsheet development and layout design of 300-ton lead-zinc mill at Chilete, Peru, built in 1951-1953; assistance in design of Triumph mill, Hailey, Idaho, built in 1952; design of 20-ton pilot plant for Buchans Mining Co., Buchans, Newfoundland, built in 1951; design of 50-ton pilot plant, Toquepala, Peru, built in 1951; and the design of a 30,000-ton copper concentrator at Toquepala, Southern Peru Copper Co., built 1956-1959; most recently, flowsheet development and design of 15,000-ton copper concentrator for the Mission mine in Arizona to be built in 1960-1961.

Mr. Weiss from 1940 on has been

active in AIME affairs and has served on committees in the El Paso Section, San Francisco Section, and was chairman of the national MBD Division, membership committee, chairman of many other committees, and a director of AIME. He also has presented and published a number of papers under the auspices of the AIME in MINING AND METALLURGY and MINING ENGINEERING.

At the present time Mr. Weiss is chairman of the Utah Section, director of the Society of Mining Engineers, chairman of the Transactions editorial committee of MINING ENGINEERING, member of the AIME committee on cooperation with CIM of which he is a member, chairman of the Rocky Mountain Minerals Conference permanent committee, member of the 50th Anniversary of Froth Flotation committee, member of nominating committee of MBD, and AIME Section delegate from the Utah Section. In addition to all these activities, Norman's hobbies are golf, bridge, and gardening.

The 1960 AIME Robert H. Richards Award will be presented to Norman Weiss at the MBD luncheon on Thursday, February 18, during the Annual Meeting at the Hotel Statler. He will also be the principal speaker on that occasion.

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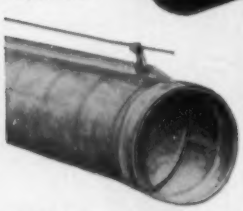

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Around the Sections

• The **Lehigh Valley Section** held its annual fall dinner meeting October 30 at the Hotel Traylor, Allentown, Pa. Raw materials research was the general theme discussed by B. J. Larpenteur and W. M. Aubrey, Bethlehem Steel Co. During the business portion of the meeting M. S. Childs reported on the Section's fund raising for the United Engineering Center. The Section has surpassed its goal.

Ladies Night on December 4 welcomed speaker Howard C. Pyle, AIME President. The ladies were entertained with Christmas decoration demonstrations presented by Mrs. Charles Behr.

New officers for 1960 are as follows: chairman, R. W. Sleeman; vice chairmen, H. J. Burnell, S. A. Ward, and C. B. Post; managers, R. M. Johnson, M. S. Childs, and N. Brown.

• First meeting for the fall for the **Utah Section** was held on September 17 with R. C. Bateman as guest speaker. His subject was *Metals in Ramjet Engines for the Space Age.*

• The November 21 meeting of the **Montana Section** was held at the Holiday Inn in Helena. The American Smelting and Refining Co. was host for dinner and R. R. Rhen, superintendent of power for Montana Power Co., was the principal speaker. Lester Zeihen also gave a slide presentation.

• The January 13 meeting of the **San Francisco Section** was held at The Engineers Club. Edward Wisser of the University of California spoke on *Structural Control of Ore Deposition in Cordilleran Ore Districts.*

• At the November 16 meeting of the **Southwest Alaska Section** the following officers were elected: Glen D. Chambers, chairman; Thomas B. Marshall, vice chairman; Charles A. Ledbetter, secretary. The executive committee: R. S. Richardson, Odin Strandberg, and Jack Crooker.

• New officers for the **Columbia Section** are: Albert E. Weissenborn, chairman, Columbia Section; Angus Y. Bethune, vice chairman, Coeur d'Alene Subsection; O. Edward Pothier, vice chairman, Snake River Subsection; John W. Cole, secretary-treasurer, Columbia Section; Douglas Baker, assistant secretary-treasurer, Coeur d'Alene Subsection; Alden J. Teske, assistant secretary-treasurer, Snake River Subsection.

• **The Colorado Section** held its December 17 meeting at the University Club in Denver with Louis G. Puls, chief design engineer of the Bureau of Reclamation, as speaker. His topic was the Colorado River Basin Reclamation Program. New officers were elected as follows: Arthur L. Hill, chairman; Alfred G. Hoyl, vice chairman; Walter L. Crow, secretary-treasurer; Frank E. Briber, Thomas C. Hiestand, and Robert R. Wichmann, directors.

• The January 6 meeting of the **Chicago Section** was held at the Chicago Bar Assn. at which John J. Bosley spoke on *Nitrogen Quench of the Experimental Blast Furnace.*

• The **St. Louis Section** heard Dr. LeRoy Scharon speak on *Geophysics —"Where Yo' Hiding?"* at the January 8 meeting in the York Hotel.

• The November 17 meeting of the **Bisbee-Douglas Subsection,** Arizona Section, met at the Top Hat Club in Douglas, Ariz. The program featured a film, *Diamond Mining in South Africa,* by Christensen Diamond Products and a talk on *Gems* by J. W. Galbraith. The following officers were elected: J. H. Ladd, chairman, S. C. Holmes, vice chairman; G. A. Dahlke, secretary; and C. A. Wenner, chairman of membership committee.

• **The Utah Section** held its final meeting of the year December 17 at the Newhouse Hotel in Salt Lake City. Dorsey Hager presented an illustrated lecture on last August's Yellowstone Park earthquake.

• The December 12 meeting of the **Montana Section** was held at the Finlan Hotel in Butte where members and their wives heard Joseph L. Gillson's illustrated lecture *Archeology in Mexico.* The new officers are: George Hanson, chairman; Guy Weaver, vice chairman; and Koehler Stout, secretary-treasurer.

• The **Washington, D. C., Section** had as its guest speakers at its December 1 meeting Howard Pyle, AIME President, and E. O. Kirkendall, Secretary. Mr. Pyle discussed the status of primary energy resources in the U. S.

At this meeting in the Broadmoor the following officers were elected: Richard W. Smith, chairman; Charles W. Merrill, J. T. Sherman, and John Croston, vice chairmen; Paul T. Allsman and Cloyd Smith, council; Albert Schreck, secretary-treasurer; and Donald Frendzel, assistant secretary-treasurer.

Personals

Felix C. Jaffe, formerly geologist with Union Carbide Ore Co., now is technical manager for Societe du Manganese de Guyane, Cayenne, French Guiana.

Ronald H. Longua graduated last June from the University of Wisconsin and became an authority engineer for U. S. Gypsum at Fort Dodge, Iowa.

Karl H. Koropp, superintendent of operations at the Utah Copper Div. refinery of Kennecott Copper Corp., has been appointed project engineer in the Western Mining Div. engineering department. **C. Arthur Zeldin,** member of the Western Mining Div. research center project development department, has been appointed to succeed Mr. Koropp as superintendent of operations at the Utah refinery.

The National Academy of Sciences, National Research Council announced the appointment of **Augustus B. Kinzel** as chairman of its Division of Engineering and Industrial Research. Dr. Kinzel, AIME Past-President, is vice president for research at Union Carbide Corp.

James F. Schumar has been named chairman of the metallurgy department of the John Jay Hopkins Laboratory which is part of the General Atomic Division of General Dynamics Corp.

Glenn C. Waterman, exploration geologist of The Anaconda Co. and formerly chief geologist at Chuquicamata, has been appointed chief geologist of The Anaconda Co. (Canada) Ltd. with offices in Toronto.

Paul Weir, chairman of the board, and **J. P. Weir,** vice president of the Paul Weir Co. in Chicago, returned from Australia where they were examining three operating mines near Sydney, New South Wales.

R. C. Hemmersbaugh is a mining engineer with The M. A. Hanna Co. in Hibbing, Minn., after his two-year tour of duty with the U. S. Army Map Service in the Far East.

Douglas Castleberry, who was superintendent of Weston & Brooker Co., now is manager of operations for W. S. Frey Co. in Martinsburg, W. Va.

Frederick L. Smith of the Utah Construction and Mining Co. has been promoted from the position of geologist to project manager.

N. B. Dismukes has been assistant production manager for **Mobil Oil Co. de Venezuela** for the past seven years and now is production manager for Mobil International Oil Co. Inc.

Thomas G. Melrose, formerly junior geologist at Oliver Iron Mining Co. in Coleraine, Minn., now is assistant geologist for Cerro de Pasco Corp. in La Oroya, Peru.

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J. D. HITCH, JR.

November elections to the board of directors of Dorr-Oliver Inc. included: **J. D. Hitch, Jr.,** president, as chairman of the board; and **L. R. Boling,** executive vice president, to succeed Mr. Hitch as president. **John V. N. Dorr** and **William L. Oliver** will continue as honorary chairman and vice chairman, respectively.

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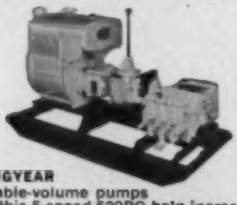

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NOTICE---SME PREPRINT AVAILABILITY

The following list of papers (from the 1960 New York Annual Meeting) will be available until Jan. 1, 1961. Coupons received with the 1960 dues bills and those distributed at the 1960 Annual Meeting will also expire on this date. Purchased coupons books will be honored on any future date. A new listing of available papers will appear in a forthcoming issue. It will include additional papers presented at the 1960 Annual Meeting (New York) and at other SME meetings throughout the year. Preprints may be obtained (upon presentation of properly filled out coupon) from SME Headquarters, 29 W. 39th St., New York 18, N. Y. Coupon books may be obtained from SME for $5 a book (10 coupons) for members or $10 a book for nonmembers. Each coupon entitles the purchaser to one preprint.

Coal (F)

Coe, G. D., and Keller, G. E.: *Tube Furnace Method for Rapid Determination of Sulfur in Coal.* **60F40**
Corriveau, M. P., and Coll, H. F.: *Solving the Flocculation Problem.* **60F59**
Davis, D. H.: *Mechanized Tamping of Mine Haulage Roads.* **60F80**
Ellison, L. D.:*Efficient Pillar Extraction by Means of Exhaust Ventilation.* **60F33**
Kamper, O. W.: *The Exploration and Mining of Raw Materials-Production of Refractory Products-Application for the Utilization of Coal.* **60F30**
Lucas, R. J.: *A Field Study in Acid Mine Drainage.* **60F35**
Mason, J.: *Daily Maintenance and Complete Overhaul of Continuous Miners.* **60F65**
Morris, F. M.: *Moss Number 3 Mine: The Materials Handling Aspect.* **60F44**
Poundstone, W.: *Face Ventilation in Development with Continuous Miners.* **60F32**
Rao, P. D., Charmbury, H. B., and Mitchell, D. R.: *Crushing of Anthracite for the Reduction of Domestic to Steam Sizes.* **60F74**
Ridenour, D. C.: *Ventilation of Very Gassy Mines Making Use of Large Diameter Bore Holes.* **60F34**
Sargeant, L.: *Ventilation of Conventional Development in Gassy Coal Mines.* **60F57**
Stachura, J. A.: *Selecting the Proper Type of Continuous Miner.* **60F49**
Updegraff, L. A.: *Continuous and Automatic Measurement of Moisture in Coal by Capacitance.* **60F21**

Economics (K)

Barr, V. L.: *A New Performance Measure to Test the Contribution of the Petroleum and Natural Gas Industry in an Expanding Economy.* **60K53**
Belton, A. E.: *Foreman's Incentive Plan.* **60K39**
Elver, R. B.: *St. Lawrence Seaway and the Canadian Mineral Industry with Particular Reference to Iron Ore.* **60K78**
Farrier, H. M.: *Trends in Property Acquisitions and Mergers in the Oil Industry Since 1954.* **60K76**
Jaworek, W. G., and Shanz, J. J., Jr.: *Bituminous Coal Consumption—Estimating Its Long Term Growth and Annual Variations.* **60K52**
Mathewson, M. H.: *Production Management Incentive Compensation Systems at I.M.C.* **60K66**
McGann, P. W.: *A Method of Projecting U. S. Petroleum Supply.* **60K64**
McGregor, J. L.: *Incentives Bonus Systems.* **60K54**
Morgan, J. D., Jr.: *U. S. Strategic Materials Stockpiles and National Strategy.* **60K50**
O'Leary, V. D.: *The Butte Contract System.* **60K22**
Peterson, W. H.: *The Question of Government Oil Import Restrictions.* **60K60**
Waterland, J. K.: *Incentive Pay System at the Homestake Mining Company.* **60K23**

Geology (I)

Gauvin, C. J.: *Geological Procedure and Control at Steep Rock Iron Mines, Ltd.* **60I45**
Macdonald, R. D.: *Iron Deposits of the Wabash Lake Area, Newfoundland, Labrador.* **60I67**
Sales, R. H.: *Critical Remarks on the Genesis of Ore as Applied to Future Mineral Exploration.* **60I79**
Schmitt, H. A.: *The Application of Geology to Mining in the Southwest.* **60I93**
Swenson, W. I.: *Geology of the Nakina Iron Property, Ontario.* **60I43**
Tupper, W. M., Jensen, M. L., and Hurley, P. M.: *The Genesis of the Sulfide Deposits of Northern New Brunswick—An Interpretation Based on Sulfur Isotopic Studies.* **60I68**

Geophysics (L)

Denen, W. H., and Linder, H.: *Relationship of Graphite in Soils to Graphite Zone.* **60L6**
Gross, G.W.: *Location of Clay Deposits by Combined Self-Potential and Resistivity Survey.* **60L2**
Hawkes, H. E.: *Status of Geochemical Prospecting in the USSR.* **60L15**
Swanson, H. E.: *Model Studies of an Apparatus for Electromagnetic Prospecting.* **60L83**

Industrial Minerals (H)

Ball, D.: *Underground Gas Storage Effects on Underground Waters.* **60H13**
Boos, M. F.: *Pegmatites and Their Mineralization in the Storm Mountain Area, Larimer.* **60H29**
Brown, O. E.: *Use of the Coultery Counter for Particle Size Analysis.* **60H71**
Castleberry, D.: *Fragmentation Studies in a Georgia Granite.* **60H20**
Cazott, J. G., Jr.: *Development of a Bauxite Deposit Using Dredging as the Stripping Method.* **60H16**
Comstock, H. B.: *Trends in Production and Use of Magnesium Compounds in the U. S.* **60H88**
Dobbs, E. H.: *Missouri-Oklahoma Type Tripoli.* **60H41**
Gillam, W. S.: *The Cost of Converted Water.* **60H14**
Hershey, R. E.: *Phosphate Raw Materials of Tennessee.* **60H17**
Hoyt, F. D., and Hartman, H. L.: *Developments and Research in the Sawing of Dimension Stone.* **60H46**
Irving, D. R.: *Some Beneficiation Techniques Applicable to Mineral Fillers.* **60H45**
Jenkinson, D. W.: *Progress Report on Beneficiation of Aggregates by Heavy Media Separation.* **60H82**
Kadey, F. L., Hutta, F. B., Jr., and Weymouth, L. E.: *A Study of the Abrasive Action of Fine Powders.* **60H56**
Kazmann, R. G.: *Water: Industrial Mineral —And Industrial Nuisance.* **60H3**
Kingman, O.: *Grade Control at Tennessee Copper Company.* **60H92**
Krueger, A.: *Quarried Stone Meets the Challenge of Contemporary Architecture.* **60H85**
Lawrence, W. G.: *Inorganic Materials Research in the USSR.* **60H9**
Piper, J. D.: *Concrete Technology in the USSR.* **60H27**
Ploetz, G. L., and Muccigrosso, A. T.: *Applications for Larthanon Oxides and Other Compounds in the Ceramic Industry.* **60H87**
Robinson, G. C.: *Lightweight Clay Block Using Vermiculture.* **60H47**
Whitman, J. H.: *Evolution and Marketing of Rare Earth Deposits, Ores, and Concentrates.* **60H42**
Wykes, C. E.: *Development of Extreme Settings on Deep Well Turbine Pumps.* **60H1**

Open Pit Mining (AO)

Hunter, P. L.: *Industrial Accident Prevention and Health.* **60AO31**
Livingston, C. W.: *The Application of Explosions Research to Blasting in Mines and Quarries.* **60AO26**
Nalle, P. B., and Weeks, L. W.: *The Use of Digital Computers in the Mining Industry.* **60AO62**
Stefanko, R.: *Underground Stress Instrumentation.* **60AO51**
Trollop, H. D.: *The Mechanics of Rock Slope.* **60AO37**

Minerals Benefication (B)

Agar, G., and Charles, R. J.: *The Size Distribution Shift in Grinding.* **60B5**
Aubrey, W. M.: *Automatic Thickener Control at Marmoraton Mining Company.* **60B25**
Bitisanes, G.: *Problems in Magnetic Roasting of Marginal Iron Ores.* **60B84**
Bleimeister, W. C., and Briston, R. J.: *Beneficiation of Rock Salt at the Detroit Mine of International Salt Co.* **60B8**
Bouchal, M. A., Detiege, A., and Robert, D.: *Magnetic Recovery of Germanium Sulphide with the Franz Ferrofilter.* **60B38**
Brison, R. G., and Tangel, O. F.: *Development of a New Dry Method for Mineral Separation.* **60B7**
Brown, J. H., Mitchell, S. R., and Weissman, M.: *Energy-Size Reduction Relationships for the Grinding of Quartz.* **60B28**
Cazort, J. G., Jr., and De Witte, J. J.: *Intra-Plant Transportation and Handling of Bauxite at Suralco's Paranam, Suriname, South America Works.* **60B81**
Dailey, W. H., Jr., and Bunge, F. H.: *The Reaction of Low Grade Nonmagnetic Iron Ores to Roasting in a Fixed Bed.* **60B58**
Edwards, J. R. J., and Salamy, S. G.: *The Magnetic Reduction of Jaspilite in a Shaft Furnace.* **60B4**
Fuerstenau, S. W.: *Retention Time in Continuous Vibrating Ball Milling.* **60B10**
Grothe, J. D.: *Laboratory Experiments and Their Relation to Plant Design.* **60B10**
Gump, J. R.: *Commercial Separation of the Heavy Rare Earths by Ion Exchange.* **60B86**
Laurila, E. A., Saari, L., and Castren, O.: *An X-Ray Fluorescence Spectrometer for the Line Analyses of Titanium in Ilmenite.* **60B19**
Lewis, C. J., and House, J. E.: *The Recovery of Molybdenum by Liquid-Liquid Extraction from Uranium Circuits.* **60B72**
Massey, E. M.: *Influence and Application of Rope Sideframe Belt Conveyors to Surface Coal Handling Facilities and Preparation Plant Design.* **60B63**
McLean, D. C.: *A Study of Oxidation and Cyanide As An Oxidation Catalyst in Pressure Leaching of Uranium.* **60B94**
Merklin, K. E., and Childs, M. M.: *Some Factors Influencing the Physical Qualities of Iron Ore Pellets.* **60B75**
Mitchell, G. R., Berman, H. L., and Goldberg, A. E.: *The Infrared Radiometric Method and Its Application to Remote Temperature Measurement.* **60B18**
Rampacek, C., and McKinney, W. A.: *The Copper Segregation Process.* **60B61**
Russell, R. J.: *Considerations in Selecting Grinding Equipment.* **60B65**
Sausa, L. E., and Martinson, J. E.: *Pulp Density Measurement and Control.* **60B24**
Schuhman, R., Jr.: *Energy Input and Size Distribution in Comminution.* **60B11**
Smith, et al. (Compilation of Abstracts).: *Symposium on Surface Phenomenon in Mineral Ceramic and Metallurgical Systems.* **60B12**
Wade, H. H., and Schulz, N. F.: *Magnetic Roasting of Iron Ores in a Traveling Grate Roaster.* **60B36**

Underground Mining (AU)

Buchanan, J. F., and Buchella, F. H.: *History and Development of the San Manuel Mine.* **60AU90**
Hayes, L. G.: *Tri-State Zinc Inc. Bowers-Campbell Mine, Timberville, Virginia.* **60AU77**
Kostuik, J., and deBastioni, M. J.: *Mine Operations at Consolidated Denison Mines Limited.* **60AU89**
Newell, T. W., and Appelin, C. W.: *Small Mine Operations—Shattuck Denn's Bardon Mine.* **60AU75**
Robbins, H. E., Dunston W. H., and Dudley, T. H.: *Andes Copper Mining Company Development of El Salvador Mine.* **60AU70**
Weehuizen, J. M.: *The Sinking of Two Shafts for the New Beatrix Mine by the Drilling Method.* **60AU91**

personals

continued

Frank Wenneis has been promoted to executive assistant to the vice president in charge of production, U. S. Borax & Chemical Corp. and has been transferred to headquarters in Los Angeles.

E. A. Slover was elected president of the New Mexico Mining Assn. at the annual meeting of members in El Paso on October 20. He is general manager of the Chino Mines Div. of Kennecott Copper Corp. **E. H. Miller,** resident manager of U. S. Borax & Chemical Co. in Carlsbad, N. M., was elected first vice president, and **L. W. Swent,** manager of Homestake-Sapin Partners, Grants, N. M., was named second vice president of the organization.

William B. York, former division industrial engineer, has been promoted to maintenance superintendent at the Utah smelter of Kennecott Copper Co. **B. Blain Bradford,** former division industrial engineer at the Nevada Mines Div. of Kennecott, succeeds Mr. York as division industrial engineer for the Utah Copper Div.

Paul W. Graff announced the sale of Graff Engineering Co. to **Walter E. Bloch.** The firm will continue its general surveying and mine surveying business from the same location, 39 East Campbell St., Blairsville, Pa. Paul W. Graff will continue his practice as consulting mining engineer from the same location.

Allan D. Gray has been elected a director of The Susquehanna Corp. He is president of Susquehanna-Western Inc., the Denver subsidiary.

W. T. ALDERSON

A. D. GARY

Ingersoll-Rand Co. has elected **W. T. Alderson** vice president. Previously he was manager of the compressor engineering department. He will be located in the New York executive offices.

Felix E. Wormser, vice president of St. Joseph Lead Co., and a trustee of Columbia University, has been elected a trustee of the American Economic Foundation.

They Blend and Reclaim From A Million Ton Stockpile

with a 10-Yard Cableway DragScraper

At this 400-ft. by 1,000-ft. storage area, ore is reclaimed from an 80-ft. stockpile to two 3,000-ltph. longitudinal conveyor slots. Ore directly over the slots is reclaimed by gravity—all remaining material is handled by a 10-yd. Cableway DragScraper.

Before the Sauerman Machine was installed, ore was moved to the slots by a small fleet of crawler units operating on the ore pile. Steep slopes and great heights made their operation hazardous.

To eliminate this and reduce labor costs, the crawlers were replaced by the Sauerman Cableway DragScraper. Now, no men are needed on the storage pile, and ore may be reclaimed from any point in the area at will. The latter feature is particularly helpful in blending the ore and insures uniform quality.

The Cableway DragScraper consists of two self-propelled towers paralleling the storage. A 10-yd. DragScraper Bucket and carriage ride the track cable suspended between them. Electrically driven drum hoists located in the towers control hauling, hoisting and conveying. Despite its size, the Sauerman unit can be operated by one man.

DragScraper Machines are built in sizes from ⅛ to 15 yds. to handle stockpiled bulk material in both outdoor and indoor storage facilities. Write or call about your requirements. We'll recommend the proper machine for you and forward appropriate literature.

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personals

continued

Ernest K. Lehmann, partner in the firm of Lindgren & Lehmann, consulting mining geologists, Minneapolis and St. Paul, has left the U. S. for an assignment in Argentina.

Emmett G. Solomon, Bunker Hill vice president and director, will act as interim chief executive officer until a new president is elected to succeed the late John D. Bradley. **Ross D. Leisk** has been appointed to fill the vacancy on the executive committee.

Don W. Drewry, formerly meteorologist for the U. S. Air Force, now is a chemist for The Bunker Hill Co. in Kellogg, Idaho.

Joseph F. Knight has been appointed manager of operations for the Kaiser Refractories & Chemicals Div., Kaiser Aluminum & Chemical Corp.

Anthony L. Payne has become associate professor of mining at Mackay School of Mines in Reno and will teach mineral exploration. He had been mining geologist with Shenon and Full in Salt Lake City.

Fredrick W. Wright, Jr., general superintendent of mining, has been appointed assistant vice president of engineering and will be located at Puerto Ordaz, Venezuela.

Peter T. Flawn will be on leave-of-absence from the Bureau of Economic Geology of The University of Texas from January to March to join the faculty of Northwestern University as a visiting lecturer in geology for the winter quarter. He will present a series of lectures on the application of petrography to tectonic problems.

J. W. BORSKEY, JR.

E. P. CADWELL

William B. Dancy has transferred to the research division of International Minerals and Chemical Corp. and will remain in Carlsbad, N. M. for the present. **J. W. Borskey, Jr.,** will fill a new position as manager, chemical operations, for the Carlsbad plant.

Edward P. Cadwell, former field engineer in Lima, Peru, has been promoted to chief metallurgist for Cyanamid International, American Cyanamid Co., with headquarters in New York.

Russel B. Caples, vice president of The Anaconda Co., retired at the end of 1959. He is continuing to act as consultant for the company. Mr. Caples began his career with Anaconda in 1910 in the Testing and Research Depts. at Anaconda, Mont. He has been vice president since 1958.

R. B. CAPLES

W. WRAITH, JR.

T. K. GRAHAM

W. H. SWAYNE

William Wraith, Jr., has been elected an assistant vice president of The Anaconda Co., and **Thomas K.**

This high capacity Amplitrol "packaged" unit bolts directly to the hopper flange. Feeds to conveyors, crushers, screens, blenders, other process equipment.

"Feeder-Hopper Bottom Package" Reduces Design, Installation Costs!

For the first time a feeder is offered as part of a complete pre-engineered feeder-hopper bottom package. When you design with Carrier Amplitrol feeders, you merely design a hopper flange to bolt to the packaged unit. *This saves you both engineering design and installation costs!*

This preassembled packaged unit is built around the revolutionary new Amplitrol feeder — first mechanical vibrating feeder with variable, stepless control—and includes the hopper bottom, flanged hopper connection, skirt plates, regulating gate, isolation and suspension supports.

The feeder-hopper bottom unit is offered in two models—one for *high capacity* applications and one for *maximum control.*

Amplitrol's exclusive long-stroke drive handles higher capacities by automatically compensating for headload. This allows larger hopper openings, reduces bridging and hang-up. The simple, fast-responding pneumatic control system operates manually or in automatic response to any standard process instrumentation.

Send for new Bulletin No. 591 describing Amplitrol "package" in detail. Carrier Conveyor Corporation, 257 North Jackson Street, Louisville, Kentucky.

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● FLATTEN BAGS

Graham is succeeding him as metallurgical manager. Mr. Graham had been assistant metallurgical manager. Other changes recently announced by Anaconda include: the retirement of **Fred W. Strandberg** as chief mining engineer in Butte after a 43-year career in the mining field. His successor is **R. Davidson Piper,** formerly assistant chief mining engineer. **John F. Harvey** becomes assistant chief mining engineer. He had been serving as engineer at the Berkeley pit. **William H. Swayne** has been appointed chief geologist of the South American Div. He had been chief geologist of the Chile Exploration Co., Anaconda subsidiary.

Lawrence A. Roe, director of development in the Research, Engineering, and Development Div. of International Minerals & Chemical Corp., has been appointed staff director, Minerals Processing, a newly created position. **Raymond E. Tuttle,** manager of capital request and cost evaluation, Agricultural Chemicals Div., succeeds Mr. Roe.

Rhodesian Selection Trust Group announces that the following appointments will become effective on April 1: **John H. Lascelles,** resident director in London; **Jack Thomson,** resident director in Lusaka, No. Rhodesia; **Frank E. Buch,** to the head office, Salisbury, So. Rhodesia, as vice president and assistant to the president; **George E. Brebner,** vice president and controller; **Noel M. Kenny,** general manager, Mufulira Copper Mines Ltd.; and **James L. Reid,** general manager, and **H. J. Wedgwood,** manager, respectively, Roan Antelope Copper Mines Ltd.

Norman Stanley has been appointed design engineer in the mechanical engineering section, Western Mining Divs., Kennecott Copper Corp.

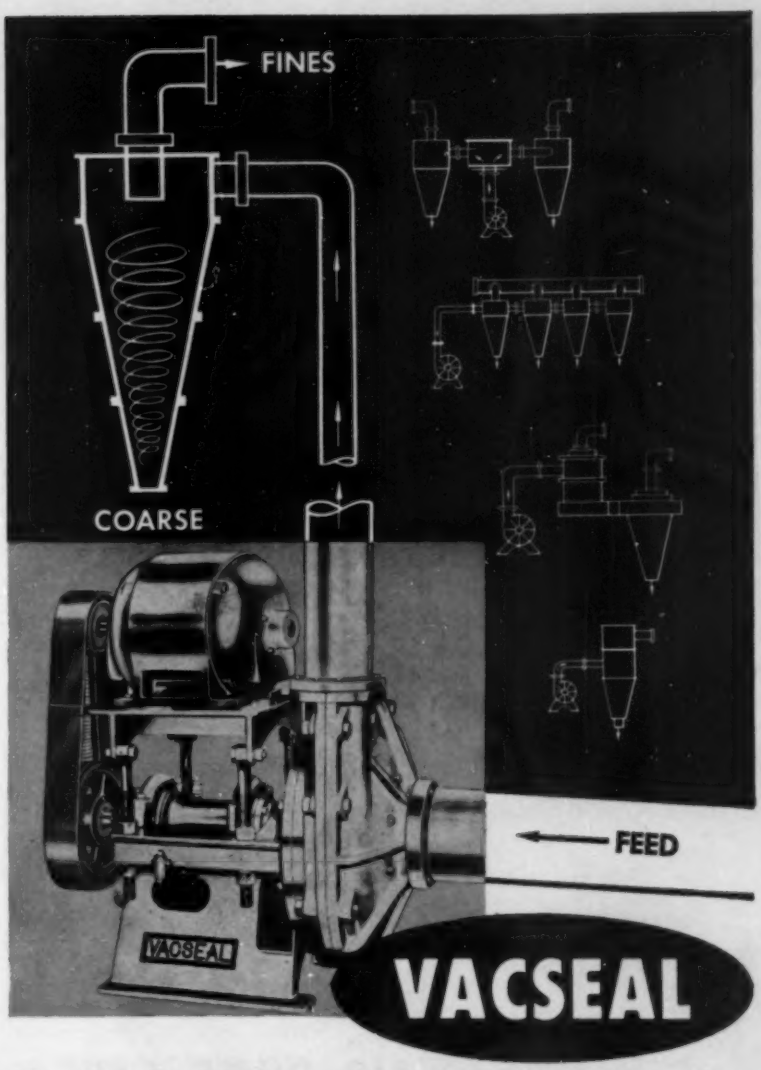
Francis W. Holbrook is new executive engineer for Western-Knapp Engineering Co., with headquarters in Chicago.

Frank B. Jewett, Jr., formerly executive vice president, has become president of Vitro Corp. of America, succeeding **J. Carlton Ward, Jr.** now chairman of the board of directors. **Charles S. Payson,** retiring board chairman, has been elected chairman of the executive committee.

W. M. PHILLIPS

E. S. FROHLING

William M. Phillips is now manager of the Southern District for the Eim-



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personals

continued

co Corp. He had been assistant manager of the district.

Edward S. Frohling is business development engineer, Eastern District, Western-Knapp Engineering Co.

William C. Lytle has retired as vice president of Atlas Powder Co. after a long career which began in 1917, only four years after the company was founded.

Rodney C. Foster is now service engineer for Ingersoll-Rand Co. and is residing in Spokane.

Karel Roos, formerly chief engineer for Northern Peru Mining Corp., is now engineer for Atlas Consolidated Mining & Development Corp., Manila, P. I.

John H. Myers has been assigned by Dorr-Oliver Inc. to Western Industrial Sales, Oakland, Calif., as industrial sales engineer.

John F. Sulzbach is now a project manager trainee with the Heavy Construction Div., H. J. Kaiser Corp., Oakland, Calif. He had been shift boss for the permafrost tunnel project, Thule, Greenland, of the U. S. Army. He reports that the latter job was rather unique, since conventional drilling and blasting methods had to be adapted to the below-freezing conditions within the tunnel.

Michael A. Price has become general superintendent of Trans-Pacific Metals Inc. He had been mine superintendent for Vitro Uranium Co.

Philip S. Wein is now a partner in Lippoth & Wein Drilling Co. after spending three years as chief engineer in charge of the mining and geology departments of Lakeview Mining Co.

After completing a 30-day orientation program of the International Cooperation Mission in Washington, D. C., **Jean W. Pressler** left in December for Seoul, Korea, to become metallurgical advisor with USOM in Korea. He had been a consulting mining and metallurgical engineer in Grants Pass, Ore.

D. L. Libbey is manager, mining and petroleum, for Dierks Forrests Inc. He had been assistant to the resident manager, U. S. Borax and Chemical Corp.

Colonel B. B. Abrams has been assigned by the Ordance Corps., U. S. Army, to the Rossford Ordnance Depot, Toledo, as commanding officer.

B. B. ABRAMS

D. L. EVERHART

Donald L. Everhart has joined International Minerals & Chemicals Corp. as chief geologist in the Mining & Exploration Dept. He had spent ten years as chief geologist for the AEC.

Raybestos-Manhattan Inc. has promoted **Arthur Arguedas** to marketing manager for conveyor and elevator belts. He had been supervisor for belt sales and engineering, central region of the company.

Dale L. Pinkerton has been transferred by Ingersoll-Rand Co. to Denver as sales engineer.

William W. Savage is now mine superintendent, Eagle Mountain Mine, Kaiser Steel Corp.

John E. Bailey, formerly safety engineer, National Lead Co., is now

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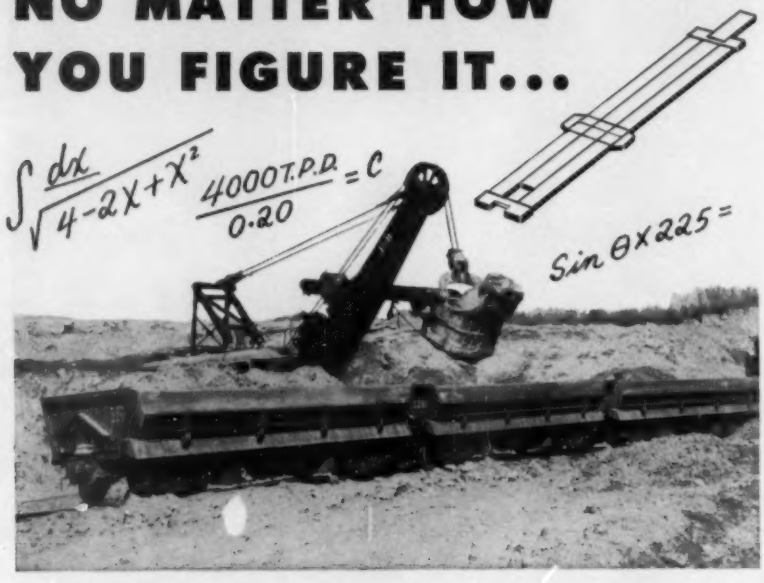

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associated with Denver-Martin Co. in the same position.

J. D. McCall has been appointed president of the Columbia-Geneva Steel Div., U. S. Steel Corp. He had been vice president-operations of the division.

John W. Phillips, formerly mine foreman and geologist, The New Jersey Zinc Co., is now mining engineer for Republic Steel Corp.

Sam Christo, who had been an engineer for U. S. Potash Co., is now field engineer for Holmes & Narver Inc., engineering and construction firm. He is now working on the Project Gnome, Carlsbad, N. M., for the AEC Facilities Div.

H. Hartjens is now senior representative for American Cyanamid Co. and is living in Lima, Peru. He had been associated with Newmont Exploration Ltd.

R. D. Schenck has been appointed assistant director of purchases for U. S. Borax & Chemical Corp. Prior to joining the company in 1949, he had been associated with Celanese Corp. of America, and Johnson & Johnson, and Hercules Powder Co.

Frederick G. von Ziegler has joined The Fresnillo Co. as metallurgist-chemist. He had been associated with Minerales de Chihuhua S. A. (Howe Sound Co.) as mill superintendent.

William John Hogg is now engineering assistant-mining with Mufulira Copper Mines Ltd. in No. Rhodesia. He had been engineer-in-charge for Uranium Valley Ltd., New Zealand.

Theodore H. Eyde has been transferred from Guadalajara, Mexico, where he was project geologist, Union Carbide Ore Co., to Tucson, Ariz., where he is project geologist for Union Carbide Nuclear Co. and is responsible for the company's exploration activities in southern Arizona.

Harry F. Haller, formerly mine superintendent, Snyder Mining Co., is now mine superintendent, Phillips Petroleum Co., Church Rock Mine.

Harry J. Wolf, consulting engineer to Lajo Mines Ltd. and Surinam Development Corp., has been elected a director of Standard Beryllium Corp. of New York.

Melvin C. Chang and **James P. McKaveney** have been appointed supervisor of chemical engineering and mineral processing and supervisor of analytical chemistry, respectively, Crucible Steel Co. of America.

Two appointments in the College of Mineral Industries, The Pennsylvania State University, include **E. F. Osborn** as vice president of research for the University and **O. Frank Tuttle** as dean of the College to succeed Dr. Osborn. Dr. Tuttle had been professor of geochemistry and chairman of the Div. of Earth Sciences.

Hardinge Rod Mill awaiting shipment to the Marquette Iron Range to grind iron ore in a flotation plant.

Hardinge ROD MILLS

Sizes range from 2' to 11½' shell diameter and up to 1000 horsepower.

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Applications include both open and closed circuit arrangements for ores, aggregates, concrete sand, cokes, and abrasives.

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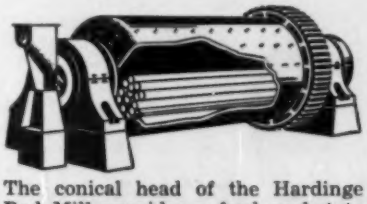

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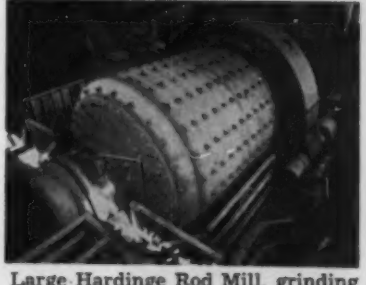

Large Hardinge Rod Mill, grinding lead-zinc ore.

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Obituaries

Louis Shattuck Cates
An Appreciation By
H. DeWitt Smith

Louis Shattuck Cates, (Honorary Member 1904) outstanding leader of this country's copper industry died in New York on Oct. 29, 1959, at the age of 77.

Born in Boston in 1881, he graduated in engineering from the Massachusetts Institute of Technology in 1902, and within two years of his graduation he found himself a job in charge of construction and development at Bingham Canyon, Utah, for the Boston Consolidated Mining Co. Here he became successively mining engineer, superintendent, and in 1910, general manager.

And here the shadow of Daniel C. Jackling, *Father of the Porphyries*, crossed his path. The Boston Consolidated had been absorbed by the Utah Copper Co., and Cates, as acting general manager of Boston Consolidated, found himself with a good contract, but no mine to manage. He explained his predicament to Jackling, who replied "Well, you haven't shown much tendency to cooperate with us. But one of the hardest things to find is a man who works wholeheartedly in the interest of his employers. I admire you for your spunk. Stay around and we will find something for you to do." Cates stayed, and thus began a 20-year association, which was invaluable to both men.

Three months later Jackling sent Cates to Ray, Ariz., for a few weeks in which to organize the operating staff at that property. These few weeks stretched into nine years for Cates, first as mine superintendent and then as general manager. Louis Cates looked on Ray as his *baby*, particularly as he had developed a novel block-caving method of mining, applied with great success to the Ray orebody. Ray was the first copper mine to produce 8000 tpd by caving methods.

In 1919 Cates was called back to Utah Copper Co., first as assistant general manager, and from 1923 to 1930, as vice president and general manager. During these 20-years at Utah and Ray, he had been recognized for his operating and administrative ability in modernization and expansion of plant.

It was because of this record of performance that Cates was offered the presidency of Phelps Dodge Corp. in 1930, which presented problems pressing for solution, from mine development through to refining and fabrication. The opportunities were great, he accepted the challenge, and in the next ten years secured, expanded, and modernized the copper refineries of Nichols Copper Co. and the copper fabricating plants of National Electric Products Corp., and added to Phelps Dodge ore reserves the important reserves of the Calumet and Arizona Mining Co. and the United Verde Copper Co.

But the most important decision in his incumbency was Mr. Cates' decision to equip the Clay orebody of the Morenci mine for production, with reserves of 450,000,000 tons of 1 pct cu ore. The original program commenced in 1937 called for mining 25,000 tpd, but by 1947 the effective capacity had been brought to 50,000 tpd, and the capital investment to launch and bring the enterprise to completion over $75,000,000. Mr. Cates was in his element in completing this project, and he was able to secure the assistance of his two major competitors in the copper business—Kennecott and Anaconda. Mr. Jackling and the Kennecott organization supplied data and advice on open-pit operations which were invaluable, and Mr. Kelley, president of The Anaconda Co., loaned Phelps Dodge his chief construction engineer, Wilbur Jurden, to supervise the huge task of design and construction of these plants. Nothing could be more indicative of Louis Cates' character and personality than his ability to secure information from his business rivals

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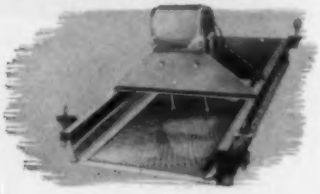

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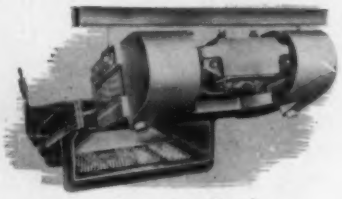

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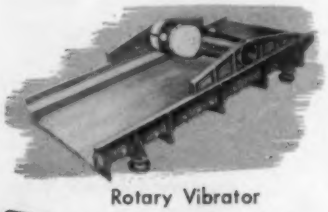

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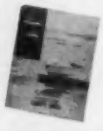

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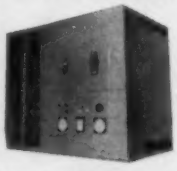

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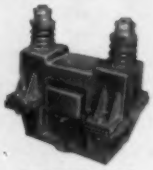

BIN VIBRATORS

to supplement the work of his own Arizona staff in launching Morenci on its smooth and successful career.

Mr. Cates became a member of AIME in 1904 and served the Institute for many years as Director, in 1934-1935 as Vice President, and in 1946 as President. He became a member of the Legion of Honor in 1954, and was elected to Honorary Membership in 1955. He was recipient of the Saunders Gold Medal in 1939, and in 1955 received the Gold Medal of the Mining and Metallurgical Soc. of America for "Distinguished Service in Mining and Related Industrial Activities."

Mr. Cates received many honors during his long business life, including Commander of the Order of the Crown (Belgium) and Chevalier of the Legion of Honor (France). He was awarded doctor's degrees from Michigan College of Mining & Technology in 1936, from University of Arizona in 1946, and from Columbia University in 1947. He was a member of the National Research Council from 1939 to 1941.

His degrees and his honors he took in his stride, but to the last of his days, Louis Shattuck Cates retained the ability to inspire deep personal affection and loyalty in his associates for this strong and simple leader of men.

Stuart Alexander Falconer
An Appreciation By
His Associates

Stuart Alexander Falconer, (Member 1945), chief metallurgist of the Mining Chemicals Dept., American Cyanamid Co., died on Apr. 25, 1959, in Stamford, Conn., after a long illness.

Stuart Falconer was born in Deloraine, Manitoba, Canada, Oct. 25, 1898. He received his early schooling in Winnipeg, Los Angeles, and Vancouver. His professional education was delayed by World War I. He served in the Canadian Army from November 1916 to April 1919 with one year of active service in France with the 3rd Div. Canadian Machine Gun Corps. Resuming his studies, Stuart Falconer entered the University of British Columbia in 1920 and graduated in 1924 with the degree of B.A.Sc. in mining engineering.

After three years with Britannia Mining & Smelting Co. and Allenby Copper Co. in B.C., he joined the Mineral Dressing Div. of the American Cyanamid Co. in 1927 and served successively as research metallurgist and field engineer; in 1954 he was appointed chief metallurgist, the position he held at his death. He was a member of CIM and the Chemical, Metallurgical, and Mining Soc. S.A.

Mr. Falconer's contributions to mineral dressing are many and are characterized by his typical thoroughness and accuracy. He will be best remembered for his pioneer work in the art of nonmetallic flotation. Of equal significance was his thoughtful and generous attitude to his fellow metallurgists; rarely did he visit a mill without leaving behind some worthwhile concrete suggestions.

His fortitude and unfailing good humor in the face of a succession of physical misfortunes was an inspiration to all those with whom he came in contact. His loss will be felt deeply by those of us who had the good fortune to work with him, and by the many good friends he had all over the world with whom he never lost contact.

He is survived by his wife Beth, a son Robert, and a daughter Mrs. Matthew D. Gailey.

Orvil R. Whitaker
An Appreciation By
John B. Carman

Orvil R. Whitaker (Legion of Honor Member 1899), 84, of 99 South Downing St., Denver, died Thanksgiving Day, Nov. 26, 1959, at Rose Memorial Hospital. Burial was at Fairmont.

Behind this simple obituary notice in the Denver newspapers lies the unsung saga of a useful man's life.

He became a member of AIME in 1899 the year following his graduation as a mining engineer from the Colorado School of Mines. Immediately on graduation, he entered mining and for all the years of an active mining career, *O. R.* or *Whit*, as his many friends knew him, was at once a friend and advisor and later, a national authority in his field.

In his earlier days, he ranged over the United States, Mexico, Canada, and Central America as an employe of several of the great mining companies in those countries.

Throughout this period, his natural abilities were enhanced by experience in operation, management, and appraisal in connection with his profession.

By 1912, he had acquired such stature in that field that he was able to set himself up as a consultant. In that capacity, he was frequently called upon to aid companies in making major decisions. Not the least of his contributions, was the men whom he selected out of his broad field of friends for topside jobs. Out of this side of his efforts, rarely talked about by him, came a devoted set of followers. The path to his Denver office was as often taken by men who came to sit at his feet for personal advice and help, as it was by hard-pressed executives who sought assurance that their course of action was the right one.

When the Raw Materials Advisory Committee of the Atomic Energy Commission was created, he was named to it and there as in the commercial field, his views were accepted as the expression of a forthright man who never stooped to personal advantage nor sought popularity

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by saying always what men desired to hear.

No single expression of the type of man *Whit* was could be found than that contained in the citation which accompanied an Award of Merit given to him in 1942 by the Colorado School of Mines as an expression of appreciation for his services as a trustee of that institution.

In essence, it describes him as the man he was—the ideal mining engineer. It discloses the traits which will cause him to be sorely missed throughout the engineering fraternity.

It follows in full:

> "AN ENGINEER:—Devoted to thorough investigation of any problem; to the determination of all of the facts; to the selection with instinctive wisdom, those pertinent to the correct solution. Concerned with performance—oblivious of praise or remuneration. A MAN:—Critical of himself—tolerant of others; doubtful of his rights—certain of his obligations; humble in the evaluation of his own achievements—laudatory of another's success."

A broad balanced mind and a generous spirit.

George F. Weaton

An Appreciation By
J. G. Wehn and C. C. Long

George F. Weaton (Member 1932) died at his home on Dec. 4, 1959. Retired as manager of Josephtown Smelter in 1954, he had served as consultant for St. Joseph Lead Co. until the end of 1958.

Born on a farm at Cherry Valley, N. Y., on July 12, 1886, Mr. Weaton went to work at an early age as an apprentice with the General Electric Co. at Schenectady. His brilliant mind, complemented by a high order of mechanical ability, brought assignment of important responsibilities in the development of the steam turbine. Success here led in 1908 to a berth as power plant engineer with the J. & P. Coates Co. whom he served with distinction until the exigencies of World War I brought association with Thomas A. Edison as chief engineer.

In 1921, St. Joseph Lead Co. called him to southeast Missouri to manage the construction and operation of the River Mines power plant. Here, Mr. Weaton pioneered developments in coal-fired boilers. So successful were his innovations in steam generation that St. Joe asked him to assist in the integration and modernization of their lead mining and milling properties.

In 1926, St. Joe began pilot plant research at Herculaneum, Mo., on an electrothermic method for producing zinc vapor from zinc sinter and coke. In a few months, there became apparent the need for a strong leader willing to take responsibility for unconventional approaches. Thus began Mr. Weaton's career as a metallurgist, a career marked by such milestones as electrothermic zinc oxide, electrothermic zinc metal, the famous Weaton-Najarian condenser, deleading of zinc concentrates, innovations in sinter manufacture, recovery of zinc metal from lead blast furnace slag.

Under Mr. Weaton's energetic leadership, Josephtown Smelter was expeditiously constructed and began operations in the last days of 1930. No severer test either of the technical and economic soundness of Mr. Weaton's metallurgical creation or of the leadership of his coterie of dedicated metallurgists can be imagined than the successful commercialization of the electrothermic process in the teeth of the nation's profoundest depression.

While Mr. Weaton's personal achievements in metallurgy, especially the electrothermic furnace epic, are brilliant in their own right, perhaps his greatest contribution to metallurgical engineering was his insistence that his younger associates develop professionally. In an industry where skeleton organizations and strict attention only to immediacies are often the rule, Mr. Weaton stood out as a prophet of the days ahead when would be recognized the economic necessity of relying on technical leadership for survival. Toward this end, he arranged for many of his associates to participate actively in the affairs of technical and professional societies. His keen interest in strengthening AIME was expressed both by copious contributions to metallurgical literature and by solid support of committee activities. Of all his many business, civic, and professional organizations, he felt closest to AIME.

His contributions to the profession both through his associates and through his personal endeavors mark George F. Weaton as an engineer of distinguished achievement. With his passing, we lose a sympathetic counsel but retain a stimulating memory.

Necrology

Date Elected	Name	Date of Death
1958	Marion K. Adams	Apr. 20, 1959
1957	Robert G. Bachtell	Sept. 28, 1959
1930	John D. Bradley	Nov. 26, 1959
1956	J. A. Buvens	Unknown
1905	Arthur H. Carpenter (Legion of Honor)	March 1956
1899	Arthur Chippendale (Legion of Honor)	Nov. 21, 1959
1949	R. C. Dempster	Oct. 24, 1959
1938	R. T. Elstad	Dec. 14, 1959
1914	Charles R. Fettke	May 26, 1959
1939	J. S. Godard	July 22, 1959
1952	Edward S. Grant	Oct. 19, 1959
1922	J. C. Haddock, Jr.	Nov. 10, 1959
1905	S. H. Hamilton (Legion of Honor)	Dec. 18, 1959
1921	George V. Hobson	Mar. 16, 1959
1909	H. E. Jackman (Legion of Honor)	Oct. 29, 1959
1956	R. E. James	Aug. 29, 1959

1956	D. C. Johnston, Jr.	Mar.	22, 1959
1956	Chet A. Kershaw	July	18, 1959
1957	H. E. Lowrey	Unknown	
1937	Clement H. Mace	Apr.	5, 1959
1946	Thomas F. McGivney	Unknown	
1937	William M. Morgan	Oct.	7, 1959
1950	Byron B. Morton	Aug.	14, 1959
1954	B. P. Mulcahy	Aug.	31, 1959
1955	James C. Neal	Aug.	15, 1959
1946	George O'Leary		1958
1914	Don H. Radcliffe	Apr.	27, 1959
1929	E. E. Rosaire	Oct.	21, 1959
1936	Robert R. Schultz	Dec.	6, 1959
1958	Adolph L. Seelinger	August	1959
1918	Erwin W. Smith	Oct.	23, 1959
1936	J. C. Spalding, Jr.	Sept.	29, 1959
1950	Fred Staats	Sept.	25, 1959
1956	P. S. Stevens	Oct.	26, 1959
1959	Garth W. Thornburg	Oct.	18, 1959
1958	Walter L. Vaughan	Oct.	30, 1959
1932	George F. Weaton	Dec.	4, 1959
1923	Edgar C. Weichel	Sept.	10, 1959
1938	Fay L. Wright	Oct.	2, 1959
1939	William F. Zerbe	Unknown	

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Proposed for Membership
Society of Mining Engineers of AIME

Total AIME membership on Dec. 31, 1959, was 33,378; in addition 2,332 Student Members were enrolled.

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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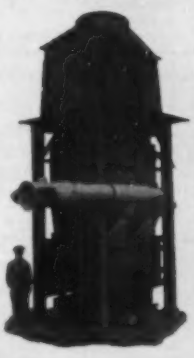

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Continued on page 190

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See pages 190 and 191

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For other items,

see

pages 188 and 189

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Bert S. Gittins Adv., Inc.

Allis-Chalmers ..... *
Klau-Van Pietersom-Dunlap, Inc.

American Brattice Cloth Corp. 176
Tri-State Adv. Co., Inc.

American Cyanamid Co. 107
James J. McMahon, Inc.

American Manganese Steel Div. American Brake Shoe Co. ..... *
The Griswold-Eshleman Co.

American Steel Foundries ..... *
Erwin Wasey, Ruthrauff & Ryan, Inc.

Anaconda Co., The ..... *
Kenyon & Eckhardt, Inc.

Armour & Co., Chemical Div. ..... *
Foote, Cone & Belding

ASEA Electric, Inc. ..... *
Mann-Ellis, Inc.

Atlas Car Manufacturing Co. ..... *
Howson Advertising

Atlas Copco 103
John Mather Lupton Co. Inc.

Bixby-Zimmer Engineering Co. ..... *
Becht & Blomeyer Inc. Adv.

Boyles Bros. Drilling Co. 186
W. S. Adamson & Assoc.

Brunner & Lay, Inc. ..... *
Norman P. Hewitt Adv.

Bucyrus-Erie Co. ..... *
Bert S. Gittins Adv.

Calumet Div. of Calumet & Hecla Inc. ..... *
Gray & Kilgore Inc. Adv.

Card Iron Works, C. S. 174
Mosher-Reimer-Williamson Adv. Agency Inc.

Carrier Conveyor Corp. 180
Doe-Anderson Adv.

Caterpillar Tractor Co. 112, 113
N. W. Ayer & Sons, Inc.

Chain Belt Co. ..... *
The Buchen Co.

Christensen Diamond Products Co. 86
Finlayson-Brown Advertising Inc.

Coates Steel Products Co. 81
Hebert-Robinson Inc. Adv.

Collins Radio Co. 83
W. D. Lyon Co.

Colorado Fuel & Iron Corp., The 84, 85
Doyle, Kitchen & McCormick, Inc.

Deister Concentrator Co., Inc. 173
Louis B. Wade, Inc.

Denver Equipment Co. ..... *
Galen E. Broyles Co., Inc.

Differential Steel Car Co. 182
Blaco Adv. Agency

Dorr-Oliver, Inc. ..... *
G. M. Basford Co.

Eimco Corp., The 101, 103
Matzie Co.

Equipment Engineers, Inc. 106
Norton M. Jacobs Adv.

Ferro Corp., Porcelain Div. ..... *
Downing Industrial Adv. Inc.

Ford Motor Co. ..... *
J. Walter Thompson, Inc.

Gallagher Co., The 181
W. S. Adamson & Assoc.

Gardner-Denver Co. 114
The Buchen Co.

General Electric Co., X-Ray Dept. ..... *
Klau-Van Pietersom-Dunlap, Inc.

Gruendler Crusher & Pulverizer Co. ..... *
Christy Humburg Adv.

Halliburton Oil Well Cementing Co. ..... **Fourth Cover**
Heintz & Co. Inc.

Hardinge Co., Inc. 183
Adams Associates, Inc.

Harnischfeger Corp. 74, 75
Fuller & Smith & Ross Inc.

Hercules Powder Co. (Explosives) ..... *
Fuller & Smith & Ross, Inc.

Humphreys Engineering Co. 102
Ed M. Hunter & Co.

Industrial Physics & Electronics Co. 185
W. S. Adamson & Assoc.

Infilco, Inc. ..... *
Willard G. Gregory & Co.

Ingersoll-Rand Co. 98
Beaumont, Heller & Sperling, Inc. Marsteller, Rickard, Gebhardt & Reed Inc.

International Harvester Co. 79
Aubrey, Finlay, Marley, & Hodgson, Inc.

International Nickel Co., The 92
Marschalk & Pratt Div., McCann-Erickson Inc.

Jeffrey Mfg. Co. ..... *
The Griswold-Eshleman Co.

Joy Mfg. Co. ..... *
Erwin Wasey, Ruthrauff & Ryan Inc., Walker Div.

Kaiser Engineers ..... *
L. C. Cole Co. Inc.

Kennedy Van Saun Mfg. & Engrg. Corp. 104
Robert S. Kampmann, Jr., Adv.

KW-Dart Truck Co. 77
Carl Lawson Adv.

Lake Shore Inc. 97
Marsteller, Rickard, Gebhardt & Reed Inc.

LeRoi Division Westinghouse Air Brake Co. 118
Hoffman, York, Paulson, Gerlach Adv. Inc.

Longyear Co., E. J. 177
Pidgeon Savage Lewis, Inc.

Mace Co. 187

Machinery Center Inc. 170
Advance Product Marketing Inc.

Mager Car Corp. ..... *
Bauer Advertising

Marion Power Shovel Co. ..... *
The Jay H. Maish Co.

Mayo Tunnel & Mine Equipment ..... *
The Godfrey Agency

Michigan Chemical Corp. ..... *
Aves, Shaw & Ring Inc.

Mine & Smelter Supply Co. 123
Walter L. Schump, Adv.

Mine Safety Appliances Co. ..... *
Ketchum, MacLeod & Grove, Inc.

Nagle Pumps, Inc. 82
Tri-State Adv. Co., Inc.

National Iron Co. ..... *
H. E. Westmoreland, Inc.

National Malleable & Steel Castings Co. 172
Palm & Patterson Inc.

Naylor Pipe Co. 108
Fred H. Ebersold, Inc.

Nordberg Mfg. Co. 88
Russell T. Gray, Inc.

Northern Blower Co. ..... *
Carr Liggett Adv., Inc.

Oldsmobile Div. General Motors Corp. 111
D. P. Brother & Co.

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The House of J. Hayden Twiss, Inc.

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Persons Advertising Inc.

Sanford-Day Iron Works, Inc. ..... *
Charles S. Kane Co.

Sauerman Brothers Inc. 179
Symonds, MacKenzie & Co. Inc. Adv.

Sheffield Div. ARMCO Steel Corp. 110
Potts · Woodbury, Inc.

Smidth & Co., F. L. 96
The Stuart Co.

Spencer Chemical Co. ..... *
Bruce B. Brewer & Co.

Sprague & Henwood, Inc. 175
Anthracite Adv.

Stearns Magnetic Products Division Indiana General Corp. ..... *
Bert S. Gittins Adv. Inc.

Stearns-Roger Mfg. Co. 95
Mosher-Reimer-Williamson Adv. Agency, Inc.

Stephens-Adamson Mfg. Co. 82
Connors Associates Inc. Adv.

Syntron Co. 184
Servad, Inc.

Texas Gulf Sulphur Co. 109
Sanger-Funnell, Inc.

Traylor Engrg. & Mfg. Div., Fuller Co. 99
Ritter-Lieberman, Inc.

Tyler Co., W. S. 119
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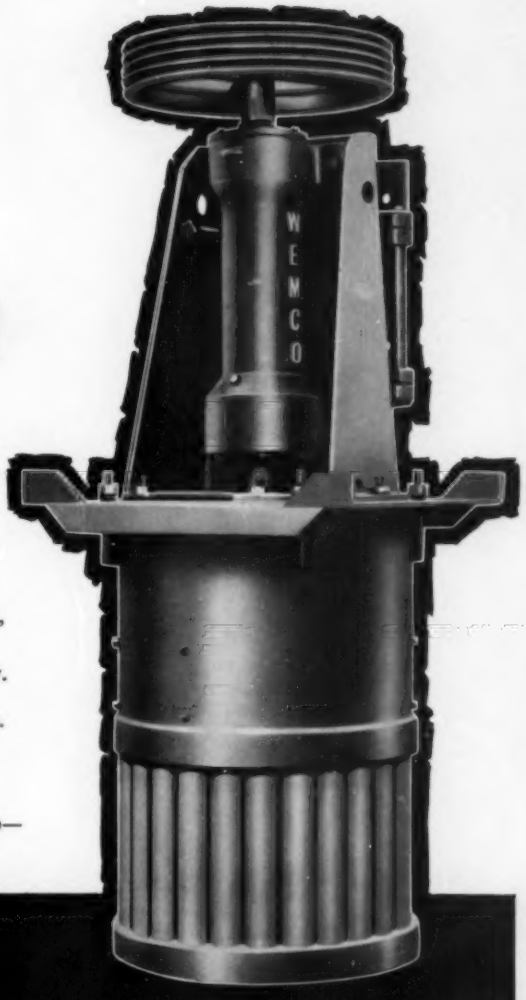

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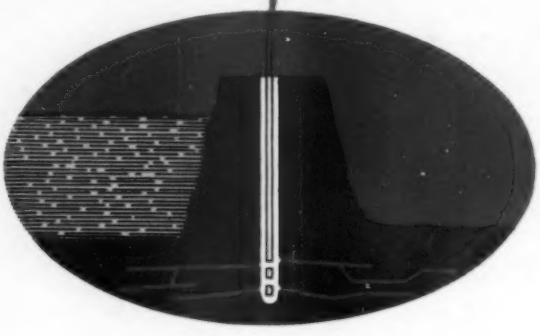

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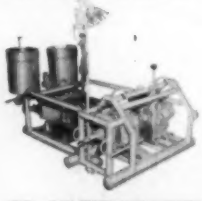

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